DEMONSTRATION OF A FULL-SCALE RETROFIT OF THE ADVANCED HYBRID PARTICULATE COLLECTOR TECHNOLOGY

TECHNICAL PROGRESS REPORT

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ABSTRACT

The Advanced Hybrid Particulate Collector (AHPC), developed in cooperation between W.L. Gore & Associates and the Energy & Environmental Research Center (EERC), is an innovative approach to removing particulates from power plant flue gas. The AHPC combines the elements of a traditional baghouse and electrostatic precipitator (ESP) into one device to achieve increased particulate collection efficiency. As part of the Power Plant Improvement Initiative (PPII), this project is being demonstrated under joint sponsorship from the U.S. Department of Energy and Otter Tail Power Company. The EERC is the patent holder for the technology, and W.L. Gore & Associates is the exclusive licensee.

The project objective is to demonstrate the improved particulate collection efficiency obtained by a full-scale retrofit of the AHPC to an existing electrostatic precipitator. The full-scale retrofit is installed on an electric power plant burning Powder River Basin (PRB) coal, Otter Tail Power Company's Big Stone Plant, in Big Stone City, South Dakota. The $13.4 million project was installed in October 2002. Project related testing will conclude in November 2004.

The following Technical Progress Report has been prepared for the project entitled "Demonstration of a Full-Scale Retrofit of the Advanced Hybrid Particulate Collector Technology" as described in DOE Award No. DE-FC26-02NT41420. The report presents the operation and performance results of the system.

POINT OF CONTACT

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LIST OF ACRONYMS

A/C	air-to-cloth ratio
AG	(Swiss, translation roughly is Incorporation or consolidation)
AHPC	advanced hybrid particulate collector
APS	aerodynamic particle sizer
COHPAC	compact hybrid particulate collector
CPC	condensation particle counter
DOE	U.S. Department of Energy
EERC	Energy & Environmental Research Center
EPA	U.S. Environmental Protection Agency
ePTFE	expanded polytetrafluoroethylene
ESP	electrostatic precipitator
FF	fabric filter
HEPA	high-efficiency particulate air
HiPPS	high-performance power system
MWh	megawatt hours
μm	micrometer
NSPS	New Source Performance Standards
O&M	operating and maintenance
OEMs	original equipment manufacturers
OTP	Otter Tail Power Company
P&ID	Piping and Intrumentation Diagram
PID	Proportional-Integral-Derivative
PJBH	pulse-jet baghouse
PM	particulate matter
PPS	polyphenylene sulfide
PRB	Powder River Basin
PJFF	pulse-jet fabric filter
P-84	aromatic polyimide fiber
QAPP	quality assurance project plan
RGFF	reverse-gas fabric filter
SCA	specific collection area
SMPS	scanning mobility particle sizer
TR	transformer-rectifier
UND	University of North Dakota
W.C.	water column

EXECUTIVE SUMMARY

This document summarizes the operational results of a project titled "Demonstration of a Full-Scale Retrofit of the Advanced Hybrid Particulate Collector Technology". The Department of Energy's National Energy Technology Laboratory awarded under a program entitled the Power Plant Improvement Initiative Program.

The advanced hybrid particulate collector (AHPC) was developed with funding from the U.S. Department of Energy (DOE). The AHPC combines the best features of electrostatic precipitators (ESPs) and baghouses in novel manner. The AHPC combines fabric filtration and electrostatic precipitation in the same housing, providing major synergism between the two methods, both in particulate collection and in transfer of dust to the hopper. The AHPC provides ultrahigh collection efficiency, overcoming the problem of excessive fine-particle emissions with conventional ESPs, and solves the problem of reentrainment and recollection of dust in conventional baghouses.

Big Stone Power Plant operated a 2.5 MWe slipstream AHPC (9000 scfm) for 1½ years. The AHPC demonstrated ultrahigh particulate collection efficiency for submicron particles and total particulate mass. Collection efficiency was proven to exceed 99.9% by one to two orders of magnitude over the entire range of particles from 0.01 to 50 μm. This level of control is well below any current particulate emission standards. These results were achieved while operating at significantly higher air-to-cloth ratios (up to 12 ft/min compared to 4 ft/min) than standard pulse-jet baghouses. To achieve 99.99% control of total particulate and meet possible stricter fine-particle standards, the AHPC is being demonstrated as the possible economic choice over either ESPs or baghouses.

Otter Tail Power Company and its partners, Montana-Dakota Utilities and NorthWestern Energy, installed the AHPC technology into an existing ESP structure at the Big Stone Power Plant. The overall goal of the project is to demonstrate the AHPC concept in a full-scale application. Specific objectives are to demonstrate 99.99% collection of all particles in the 0.01 to 50 μm size range, low pressure drop, overall reliability of the technology and long-term bag life.

A significant amount of work has taken place on the system this quarter. All of the PPS bags were removed from service during a schedule plant shutdown in June. These bags were replaced with P-84 bags. One full chamber of flow baffles was installed during the outage as well.

The plans to review the installation of Advanced Hybrid components in the inlet field continue to be evaluated. It has not yet been determined if this will proceed but, as engineering would need to start in the next quarter to meet the April 15th deadline, this decision will be forced.

PROJECT NOMENCLATURE DISCUSSION

When this technology was originally developed, the device was referred to as the "Advanced Hybrid Particulate Collector". Since the original development, from concept to an attempt at a commercial demonstration, the name of the technology has changed to "Advanced Hybrid^{TM}". This name was trademarked by W.L. Gore and Associates, Inc. to aid in the commercialization effort and tries to maintain the continuity of the successful history to date. Either "Advanced Hybrid Particulate Collector" (AHPC) or "Advanced Hybrid^{TM}" refers to the same process and equipment.

1.0 INTRODUCTION

The *Advanced Hybrid*™ filter combines the best features of ESPs and baghouses in a unique approach to develop a compact but highly efficient system. Filtration and electrostatics are employed in the same housing, providing major synergism between the two collection methods, both in the particulate collection step and in the transfer of dust to the hopper. The *Advanced Hybrid*™ filter provides ultrahigh collection efficiency, overcoming the problem of excessive fine-particle emissions with conventional ESPs, and solves the problem of reentrainment and re-collection of dust in conventional baghouses.

The goals for the *Advanced Hybrid*™ filter are as follows: > 99.99% particulate collection efficiency for particle sizes ranging from 0.01 to 50 μm, applicable for use with all U.S. coals, and cost savings compared to existing technologies.

The electrostatic and filtration zones are oriented to maximize fine-particle collection and minimize pressure drop. Ultrahigh fine-particle collection is achieved by removing over 90% of the dust before it reaches the fabric and using a GORE-TEX® membrane fabric to collect the particles that reach the filtration surface. Charge on the particles also enhances collection and minimizes pressure drop, since charged particles tend to form a more porous dust cake. The goal is to employ only enough ESP plate area to precollect approximately 90% of the dust. ESP models predict that 90%–95% collection efficiency can be achieved with full-scale precipitators with a specific collection area (SCA) of less than 100 ft^2/kacfm (1, 2). FF models predict that face velocities greater than 12 ft/min are possible if some of the dust is precollected and the bags can be adequately cleaned. The challenge is to operate at high A/C ratios (8–14 ft/min) for economic benefits while achieving ultrahigh collection efficiency and controlling pressure drop. The combination of GORE-TEX® membrane filter media (or similar membrane filters from other manufacturers), small SCA, high A/C ratio, and unique geometry meets this challenge.

Studies have shown that FF collection efficiency is likely to deteriorate significantly when the face velocity is increased (3, 4). For high collection efficiency, the pores in the filter media must be effectively bridged (assuming they are larger than the average particle size). With conventional fabrics at low A/C ratios, the residual dust cake serves as part of the collection media, but at high A/C ratios, only a very light residual dust cake is acceptable, so the cake cannot be relied on to achieve high collection efficiency. The solution is to employ a sophisticated fabric that can ensure ultrahigh collection efficiency and endure frequent high-energy cleaning. In addition, the fabric should be reliable under the most severe chemical environment likely to be encountered (such as high SO_3).

Assuming that low particulate emissions can be maintained through the use of advanced filter materials and that 90% of the dust is precollected, operation at face velocities in the range of 8–14 ft/min should be possible, as long as the dust can be effectively removed from the bags and transferred to the hopper without significant redispersion and re-collection. With pulse-jet cleaning, heavy residual dust cakes are not typically a problem because of the fairly high cleaning energy that can be employed. However, the high cleaning energy can lead to significant redispersion of the dust and subsequent re-collection on the bags. The combination of a very high-energy pulse and a very light dust cake tends to make the problem of redispersion much worse. The barrier that limits operation at high A/C ratios is not so much the dislodging of dust from the bags as it is the transferring of the dislodged dust to the hopper. The *Advanced Hybrid*™ filter achieves enhanced bag cleaning by employing electrostatic effects to precollect a significant portion of the dust and by trapping in the electrostatic zone the redispersed dust that comes off the bags following pulsing.

1.1 History of Development

The *Advanced Hybrid*™ filter concept was first proposed to DOE in September 1994 in response to a major solicitation addressing air toxics. DOE has been the primary funder of the *Advanced Hybrid*™ filter development since that time, along with significant cost-sharing from industrial cosponsors. Details of all of the results have been reported in DOE quarterly technical reports, final technical reports for completed phases, and numerous conference papers. A chronology of the significant development steps for the *Advanced Hybrid*™ filter is shown below.

- September 1994 - *Advanced Hybrid*™ filter concept proposed to DOE
- October 1995 - September 1997 - Phase I - *Advanced Hybrid*™ filter successfully demonstrated at 0.06-MW (200-acfm) scale
- March 1998 - February 2000 - Phase II - *Advanced Hybrid*™ filter successfully demonstrated at 2.5-MW (9000-acfm) scale at Big Stone Plant
- September 1999 - August 2001 - Phase III - *Advanced Hybrid*™ filter commercial components tested and proven at 2.5-MW scale at Big Stone Plant
- Summer 2000 – Minor electrical damage on bags first observed
- January–June 2001 – To prevent electrical damage, the *Advanced Hybrid*™ filter perforated plate configuration was developed, tested, and proven to be superior to the original design
- July 2001 - December 2004 - Mercury Control with the *Advanced Hybrid*™ Filter - Extensive additional testing of the perforated plate concept was conducted with the 2.5-MW pilot unit

1.2 Design of the Perforated Plate *Advanced Hybrid*™ Filter Configuration

After bag damage was observed in summer 2000, extensive experiments were carried out at an Energy & Environmental Research Center (EERC) laboratory to investigate the interactions between electrostatics and bags under different operating conditions. The 200-acfm *Advanced Hybrid*™ filter was first operated without fly ash under cold-flow conditions with air. The effects of electrode type, bag type, plate-to-plate spacing, the relative distance from the electrodes to plates compared to the distance from the electrodes to the bags (spacing ratio), and various grounded grids placed between the electrodes and bags were all evaluated. Several of the conditions from the cold-flow tests were selected and further evaluated in hot-flow coal combustion tests. While all of these tests resulted in very low current to the bags, there appeared to be a compromise in overall *Advanced Hybrid*™ filter performance for some configurations.

A configuration that appeared to have promise was a perforated plate design in which a grounded perforated plate was installed between the discharge electrodes and the bags to protect the bags. On the opposite side of the electrodes, another perforated plate was installed to simulate the geometric arrangement where each row of bags would have perforated plates on both sides, and no solid plates were used. The discharge electrodes were then centered between perforated plates located directly in front of the bags. With this arrangement, the perforated plates function both as the primary collection surface and as a protective grid for the bags. With the 200-acfm *Advanced Hybrid*™ filter, the perforated plate configuration produced results far better than in any previous *Advanced Hybrid*™ filter tests and provided adequate protection of the bags.

Based on the 200-acfm results, a perforated plate configuration was designed and installed on the 9000-acfm slipstream pilot unit at the Big Stone Power Plant. The differences between the new perforated plate design and the previous *Advanced Hybrid*™ filter can be seen by comparing Figure 1 with Figure 2. Figure 1 is a simplified top view of the 9000-acfm *Advanced Hybrid*™ filter configuration at the start of Phase III, which had a plate-to-plate spacing of 23.6 in. For the perforated plate configuration (Figure 2), the bag spacing was not changed, allowing use of the same tube sheet as in the previous configuration (Figure 1). However, the distance from the discharge electrodes to the perforated plates as well as the distance from the bags to the perforated plates can be reduced without compromising performance. Therefore, one of the obvious advantages of the perforated plate configuration is the potential to make the *Advanced Hybrid*™ filter significantly more compact than the earlier design.

Another difference is that directional electrodes are not required with the perforated plate design. With the previous design, directional electrodes (toward the plate) were needed to prevent possible sparking to the bags. This means that conventional electrodes can be used with the *Advanced Hybrid*™ filter. Electrode alignment is also less critical because an out-of-alignment electrode would simply result in potential sparking to the nearest grounded perforated plate, whereas with the old design, an out-of-alignment electrode could result in sparking to a bag and possible bag damage.

While the perforated plate configuration did not change the overall *Advanced Hybrid*™ filter concept (precollection of > 90% of the dust and enhanced bag cleaning), the purpose of the plates did change. The perforated plates serve two very important functions: as the primary collection surface and as a protective grid for the bags. With approximately 45% open area, there is adequate collection area on the plates to collect the precipitated dust while not restricting the flow of flue gas toward the bags during normal filtration. During pulse cleaning of the bags, most of the reentrained dust from the bags is forced back through the perforated plates into the ESP zone. The 9000-acfm results as well as the 200-acfm results showed better ESP collection than the previous design while maintaining good bag cleanability. The better

ESP collection efficiency is likely the result of forcing all of the flue gas through the perforated plate holes before reaching the bags. This ensures that all of the charged dust particles pass within a maximum of one-half of the hole diameter distance of a grounded surface. In the presence of the electric field, the particles then have a greater chance of being collected. In the old *Advanced Hybrid*™ filter design, once the gas reached the area between the electrodes and bags, it would be driven toward the bags rather than the plates, and a larger fraction of the dust was likely to bypass the ESP zone.

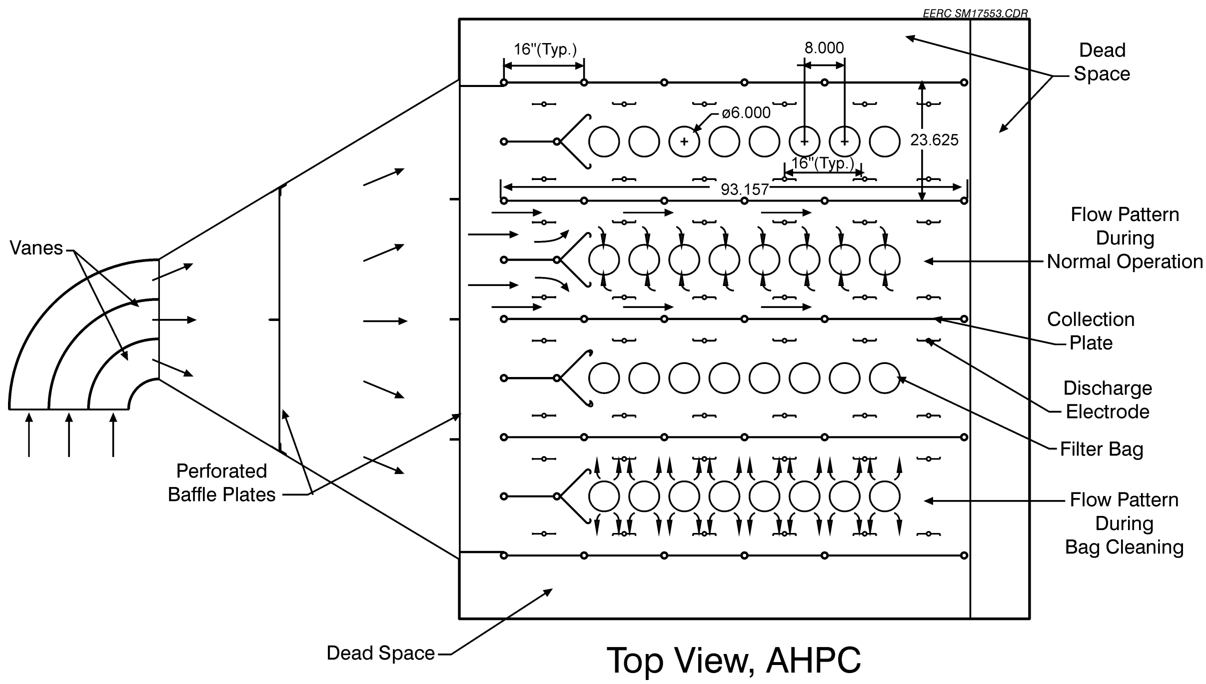


Figure 1. Top view of the old configuration for the 9000-acfm *Advanced Hybrid*™ filter at Big Stone.

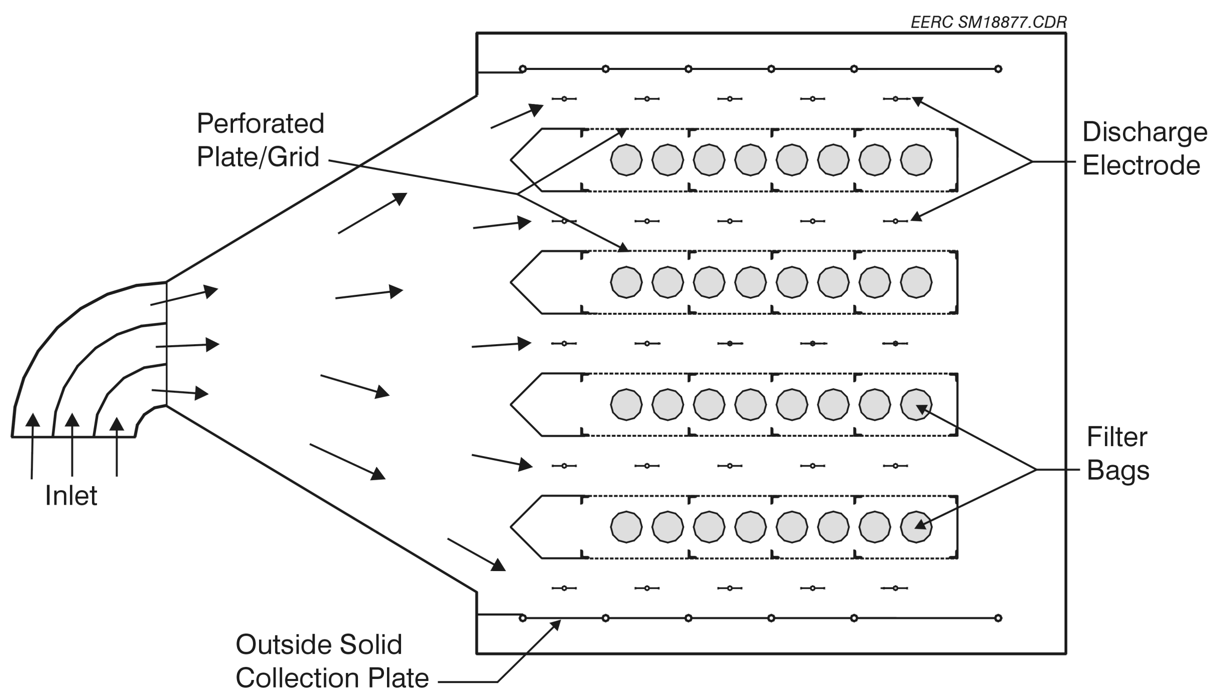


Figure 2. Top view of the perforated plate configuration for the 9000-acfm *Advanced Hybrid*™ filter.

1.3 Pressure Drop Theory and Performance Evaluation Criteria

Pressure drop across the bags is one of the main operational parameters that defines overall performance. It must be within capacity limits of the boiler fans at the maximum system flow rate. Since acceptable pressure drop is so critical to successful operation, a detailed discussion of the theory and factors that control pressure drop follows.

For viscous flow, pressure drop across a FF is dependent on three components:

$$dP = K_f V + K_2 W_R V + \frac{K_2 C_i V^2 t}{7000} \quad \text{[Eq. 1]}$$

where:

dP = differential pressure across baghouse tube sheet (in. W.C.)
K_f = fabric resistance coefficient (in. W.C.-min/ft)
V = face velocity or A/C ratio (ft/min)
K_2 = specific dust cake resistance coefficient (in. W.C.-ft-min/lb)
WR = residual dust cake weight (lb/ft^2)
C_i = inlet dust loading (grains/acf)
t = filtration time between bag cleaning (min)

The first term in Eq. 1 accounts for the pressure drop across the fabric. For conventional fabrics, the pore size is quite large, and the corresponding fabric permeability is high, so the pressure drop across the fabric alone is negligible. To achieve better collection efficiency, the pore size can be significantly reduced, without making fabric resistance a significant contributor to pressure drop. The GORE-TEX® membrane filter media allows for this optimization by providing a microfine pore structure while maintaining sufficient fabric permeability to permit operation at high A/C ratios. A measure of the new fabric permeability is the Frazier number which is the volume of gas that will pass through a square foot of fabric sample at a pressure drop of 0.5 in. W.C. The Frazier number for new GORE-TEX® bags is in the range from 4 to 8 ft/min. Through the filter, viscous (laminar) flow conditions exist, so the pressure drop varies directly with flow velocity. Assuming a new fabric Frazier number of 6 ft/min, the pressure drop across the fabric alone would be 1.0 in. W.C. at an A/C ratio (filtration velocity) of 12 ft/min.

The second term in Eq. 1 accounts for the pressure drop contribution from the permanent residual dust cake that exists on the surface of the fabric. For operation at high A/C ratios, the bag cleaning must be sufficient to maintain a very light residual dust cake and ensure that the pressure drop contribution from this term is reasonable. The contribution to pressure drop from this term is one of the most important indicators of longer-term bag cleanability.

The third term in Eq. 1 accounts for the pressure drop contribution from the dust accumulated on the bags since the last bag cleaning. K_2 is determined primarily by the fly ash particle-size distribution and the porosity of the dust cake. Typical K_2 values for a full dust loading of pulverized coal (pc)-fired fly ash range from about 4 to 20 in. W.C.-ft-min/lb but may, in extreme cases, cover a wider range. Within this term, the bag-cleaning interval, t, is the key performance indicator. The goal is to operate with as long of a bag-cleaning interval as possible, since more frequent bag pulsing can lead to premature bag failure and require more energy consumption from compressed air usage. An earlier goal for the pilot-scale tests was to operate with a pulse interval of at least 10 min while operating at an A/C ratio of 12 ft/min. While this goal was exceeded in the pilot-scale tests, a pulse interval of only 10 min is now considered too short to demonstrate good *Advanced Hybrid*™ filter performance over a longer period. With a shorter pulse interval, the *Advanced Hybrid*™ filter does not appear to make the best use of the electric field, because of the reentrainment that occurs just after pulsing. Current thought is that a pulse interval of at least 60 min is needed to demonstrate the best long-term performance.

Total tube sheet pressure drop is another key indicator of overall performance of the *Advanced Hybrid*™ filter. Here, the goal was to operate with a tube sheet pressure drop of 8 in. W.C. at an A/C ratio of 12 ft/min. Note that the average pressure drop is not the same as the pulse-cleaning trigger point. For many of the previous and current tests, the pulse trigger point was set at 8 in. W.C., but the average pressure drop was significantly lower.

To help analyze filter performance, the terms in Eq. 1 can be normalized to the more general case by dividing by velocity. The dP/V term is commonly referred to as drag or total tube sheet drag, D_T:

$$\frac{dP}{V} = D_T = K_f + K_2 W_R + \frac{K_2 C_i V t}{7000} \quad \text{[Eq. 2]}$$

The new fabric drag and the residual dust cake drag are typically combined into a single term called residual drag, D_R:

$$D_T = D_R + \frac{K_2 C_i V t}{7000} \quad \text{[Eq. 3]}$$

The residual drag term then is the key indicator of how well the bags are cleaning over a range of A/C ratios, but may still be somewhat dependent on A/C ratio. For example, it may be more difficult to overcome a dP of 10 in. W.C. to clean the bags than cleaning at a dP of 5 in. W.C. For most baghouses, the residual drag typically climbs somewhat over time and must be monitored carefully to evaluate the longer-term performance. Current thought is that excellent *Advanced Hybrid*™ filter performance can be demonstrated with a residual drag value of 0.6 or lower.

Between bag cleanings, from the second term in Eq. 3, the drag increases linearly with K_2 (dust cake resistance coefficient), C_i (inlet dust concentration), V (filtration velocity), and t (filtration time). For conventional baghouses, the C_i term is easily determined from an inlet dust loading measurement, and approximate K_2 values can be determined from the literature or by direct measurement. However, for the *Advanced Hybrid*™ filter, the concentration of the dust that reaches the bags is generally not known and would be very difficult to measure experimentally. From the Phase I laboratory tests, results indicated approximately 90% of the dust was precollected and did not reach the fabric. However, this amount is likely to fluctuate significantly with changes to the electrical field and with the dust resistivity. Since C_i is not known, for evaluation of *Advanced Hybrid*™ filter performance, the K_2 and C_i can be considered together:

$$K_2C_i = \frac{(D_T - D_R)7000}{Vt} \qquad \text{[Eq. 4]}$$

Evaluation of K_2C_i can help in assessing how well the ESP portion of the *Advanced Hybrid*™ filter is functioning, especially by comparing with the K_2C_i during short test periods in which the ESP power was shut off. For the Big Stone ash, the K_2C_i value has typically been about 20 without the ESP field. For the 9000-acfm pilot *Advanced Hybrid*™ filter, longer-term K_2C_i values of 1.0 have been demonstrated with the ESP field on, which is equivalent to 95% precollection of the dust by the ESP. Again, the goal is to achieve as low of a K_2C_i value as possible; however, good *Advanced Hybrid*™ filter performance can be demonstrated with K_2C_i values up to 4, but this is interdependent on the residual drag and filtration velocity.

Eq. 4 can be solved for the bag-cleaning interval, t, as shown in Eq. 5. The bag-cleaning interval is inversely proportional to the face velocity, V, and the K_2C_i term and directly proportional to the change in drag before and after cleaning (delta drag). The delta drag term is dependent on the cleaning set point or maximum pressure drop as well as the residual drag. The face velocity, delta drag, and K_2C_i terms are relatively independent of each other and should all be considered when the bag-cleaning interval is evaluated. However, as mentioned above, the drag may be somewhat dependent on velocity if the dust does not clean off the bags as well at high velocity as at low velocity. Similarly, the K_2C_i is somewhat dependent on velocity for a constant plate collection area. At the greater flow rates, the SCA of the precipitator is reduced, which will result in a greater dust concentration, C_i, reaching the bags.

$$t = \frac{(D_T - D_R)7000}{VK_2C_i} \qquad \text{[Eq. 5]}$$

By evaluating these performance indicators, the range in possible A/C ratios can be calculated by using Eq. 1. For example, using the acceptable performance values of a 60-min pulse interval and a residual drag of 0.6, Eq. 1 predicts that a K_2C_i value of 2.33 would be needed when operating at an A/C ratio of 10 ft/min and a pulse trigger of 8 in. W.C. Obviously, deterioration in the performance of one indicator can be offset by improvement in another. Results to date show that performance is highly sensitive to the A/C ratio and that excellent *Advanced Hybrid*™ filter performance can be achieved as long as a critical A/C ratio is not exceeded. If the A/C ratio is pushed too high, system response is to more rapidly pulse the bags. However, too rapid of pulsing tends to make the residual drag increase faster and causes the K_2C_i to also increase, both of which lead to poorer performance. The design challenge is to operate the *Advanced Hybrid*™ filter at the appropriate A/C ratio for a given set of conditions.

1.4 9000-acfm Pilot-Scale Results

During the summer of 2002 the 9000-acfm *Advanced Hybrid*™ filter was operated from June 28 through early September with minimal changes to the operating parameters. This is the longest time the pilot unit was operated without interruption and is the best example of the excellent performance demonstrated with the 9000-acfm *Advanced Hybrid*™ filter. One of the main objectives of the summer 2002 tests was to assess the effect of carbon injection for mercury control on longer-term *Advanced Hybrid*™ filter performance. In order to achieve steady-state *Advanced Hybrid*™ filter operation prior to starting carbon injection, the *Advanced Hybrid*™ filter was started with new bags on June 28 and operated continuously until the start of the carbon injection for mercury control in August. Operational parameters are given in Table 1, and the bag-cleaning interval, pressure drop, and K_2C_i data from June 28 to September 3 are shown in Figures 3-5. The daily average pressure drop data increased slightly with time as would be expected after starting with new bags. When the carbon was started on August 7, there was no perceptible change in pressure drop. The bag-cleaning interval was somewhat variable as a result of temperature and load swings, but, again there was no increase when the carbon feed was started. The K_2C_i values are an indication of the amount of dust that reaches the bags and subsequently relate to how well the ESP portion of the *Advanced Hybrid*™ filter is working. Again, there was no perceptible change when the carbon was started. These data show that the *Advanced Hybrid*™ filter can be expected to provide good mercury removal with upstream injection of carbon without any adverse effect on performance.

From August 21 to August 26, the *Advanced Hybrid*™ filter current was deliberately reduced to 25 mA compared to the normal 55 mA setting (see Figures 3-5) to see if good mercury removal could be maintained. The bag-cleaning interval dropped to about one-half, and the K_2C_i value approximately doubled, which would be expected. Both of these indicate that about twice as much dust reached the bags at 25 mA compared to 55 mA. However, almost no effect on pressure drop was seen. This implies that it should be possible to optimize *Advanced Hybrid*™ filter operational parameters to get the best overall mercury removal while maintaining good *Advanced Hybrid*™ filter performance.

Table 1. 2.5-MW *Advanced Hybrid*™ Filter Test Parameters and Operational Summary, June 28 - September 2, 2002

A/C Ratio	10 ft/min
Pulse Pressure	70 psi
Pulse Duration	200 ms
Pulse Sequence	87654321 (multibank)
Pulse Trigger	8.0 in. W.C.
Pulse Interval	260 - 400 min
Temperature	260° - 320°F
Rapping Interval	15 - 20 min
Voltage	58 - 62 kV
Current	55 mA

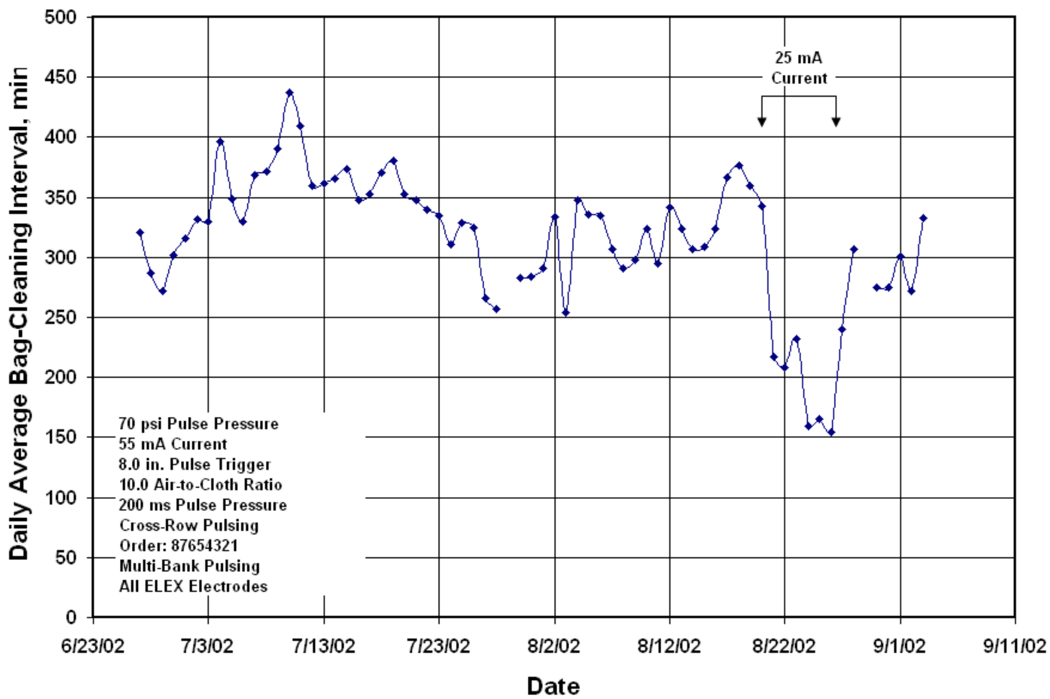


Figure 3. Daily average bag-cleaning interval for summer 2002 tests with the 9000-acfm *Advanced Hybrid*™ filter.

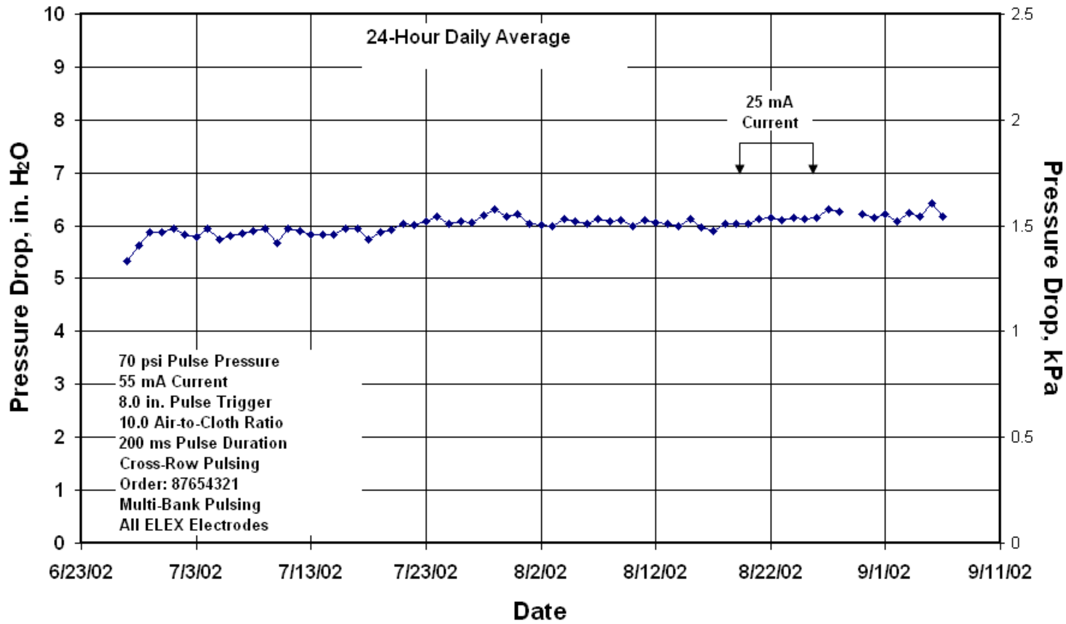


Figure 4. Daily average pressure drop for summer 2002 tests with the 9000-acfm *Advanced Hybrid*™ filter.

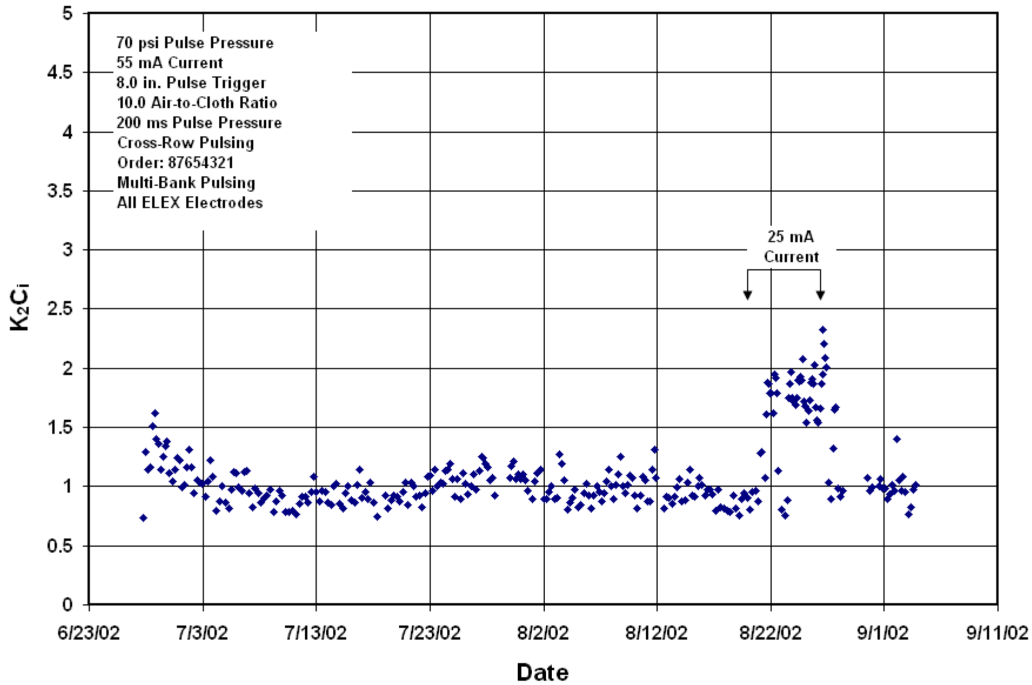


Figure 5. K_2C_i for summer 2002 tests with the 9000-acfm *Advanced Hybrid*™ filter.

A summary of the results in Table 2 shows the excellent operational performance achieved with the 9000-acfm at an A/C ratio of 10 ft/min.

Table 2. Summary of 9000-acfm Pilot-Scale Results from Summer 2002

A/C Ratio	10 ft/min
Average dP	~6 in. W.C.
Bag-Cleaning Interval	2–5 hr
Residual Drag	0.4–0.5
K_2C_i	0.9–1.5

The 9000-acfm pilot *Advanced Hybrid*™ filter was also used to vary the operational parameters to assess the most critical effects. One of the most important findings was the observed significant effect of the pulse interval on the K_2C_i value, as shown in Figure 6. The large increase in K_2C_i at the lowest pulse intervals indicates that the benefit of the electric field is diminished at lower pulse intervals. This indicates that for good *Advanced Hybrid*™ filter performance, a minimum allowable pulse interval should be established. Based on Figure 6, a 60 min pulse interval would be a good minimum performance goal.

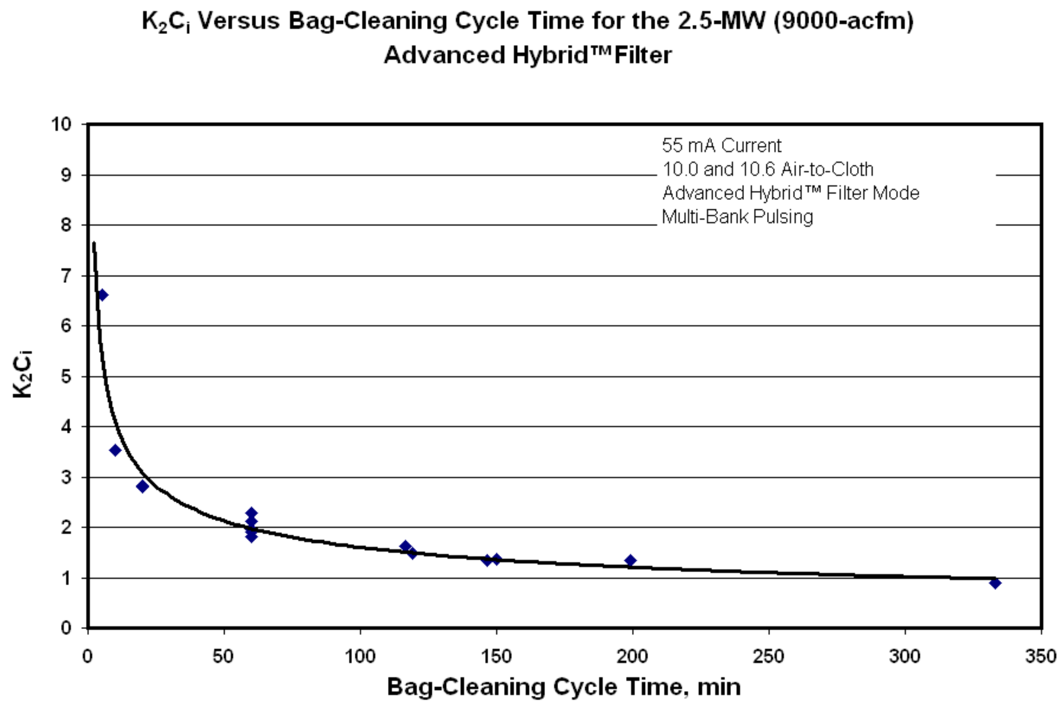


Figure 6. Effect of pulse interval on K_2C_i for 9000-acfm pilot *Advanced Hybrid*™ filter.

1.5 Full-Scale Design and Differences Between Full and Pilot Scale

The original ESP at Big Stone consisted of a Lurgi-Wheelabrator design with four main chambers and four collecting fields in series within each chamber. Only the last three fields in each chamber were converted into an *Advanced Hybrid*™ filter while the first field was unchanged (Figure 7). Since the ESP plates are 40 ft high, but the *Advanced Hybrid*™ filter bags are only 23 ft long, there is a large open space between the bottom of the bags and the hoppers (Figure 8). The outer six compartments (Figure 7) are arranged with 20 rows and 21 bags per row, while the six inner compartments have 19 rows with 21 bags per row. The total number of planned bags for the 12 compartments was 4914. However, because of a spacing limitation from the electrode rapping mechanism, a total of 81 bags had to be removed, so the total number of bags in service is 4834.

The main differences between the 2.5-MW pilot *Advanced Hybrid*™ filter and the full-scale Big Stone *Advanced Hybrid*™ filter are as follows:

- The pilot unit has a small precollection zone consisting of one discharge electrode, while the full-scale unit has no precollection zone (without the first field on). The effect would be better ESP collection (lower K_2C_i) in the pilot unit. The pilot unit has shorter bags, 15 ft versus 23 ft for the full-scale *Advanced Hybrid*™ filter. The expected result would be better bag cleaning with the pilot unit (lower residual drag).

- The full-scale *Advanced Hybrid*™ filter has an ESP plate spacing of 12 in. compared to 13.5 in. for the pilot-scale unit. The expected result is somewhat better ESP collection efficiency.

- The entrance velocity of the flue gas is 4–8 ft/s for the full-scale unit versus 2 ft/s in the pilot-scale unit. The expected effect is better ESP collection efficiency with the pilot unit.

- The pilot unit has very uniform side inlet flow distribution while the full-scale *Advanced Hybrid*™ filter has flow from the side for the first *Advanced Hybrid*™ filter compartment and from the bottom in the back 2 compartments.

In the pilot unit all of the flow is uniformly distributed from the side and none of the flow comes from the bottom. In the full-scale *Advanced Hybrid*™ filter, flow entering the first *Advanced Hybrid*™ filter chamber comes from the side (similar to the pilot unit). The flow to the back two compartments must first travel below the first *Advanced Hybrid*™ filter compartment and then either directly up from the bottom into the compartment or up from the bottom into the areas between compartments and then horizontally into the compartments (Figure 9).

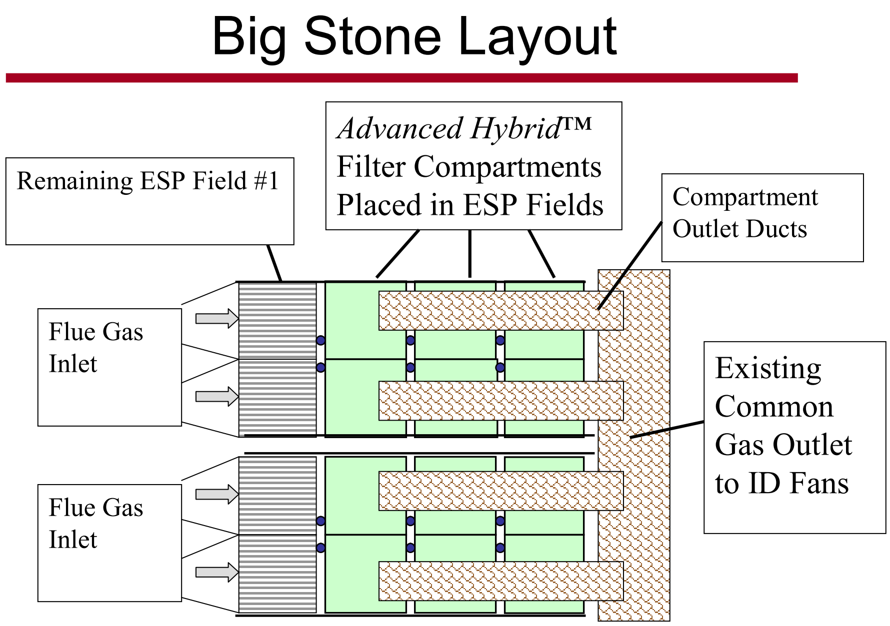


Figure 7. Top view of the *Advanced Hybrid*™ filter full-scale retrofit configuration at Big Stone.

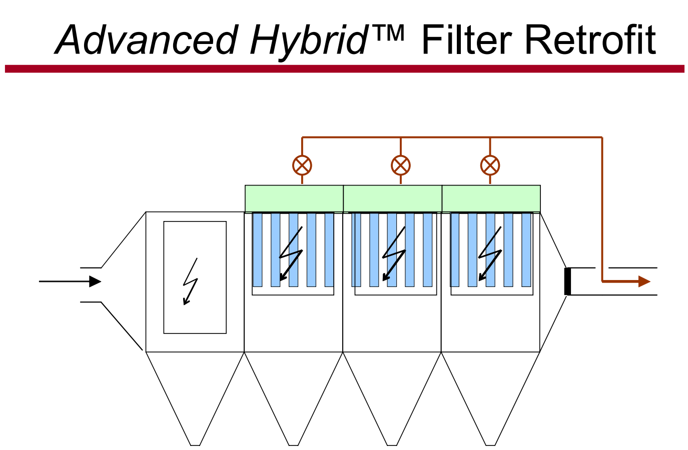


Figure 8. Side view of the *Advanced Hybrid*™ filter full-scale retrofit configuration at Big Stone.

2.0 EXPERIMENTAL

2.1 Independent Characteristics

2.1.1 Independent Characteristic Chart

The following chart lists the specific independent characteristics of the Advanced Hybrid System. If changes are made to the independent data, they will be described in the section listed under the "Notes" column.

Table 3.

Data	Status	Notes
ESP Collecting Surface	170,500 ft^2	Unchanged
# of Discharge Electrodes	2,706	Unchanged
# of Filter Bags	4833	Unchanged
Filter Bag Dimensions	7 Meters Long, 6 Inches Diameter	Unchanged
Filter Bag Surface Area	36.07 ft^2	Unchanged
Filter Bag Material	See 2.1.2	Unchanged
Pulse Pressure	80 psi	Unchanged
Cleaning Mode	Threshhold Cleaning	Unchanged
TR Rating of AH Field	1500 ma, 55 kV	Unchanged
TR Rating of Inlet ESP Field	2000 ma, 55 kV	Unchanged
Inlet ESP Field Data		
Inlet Field Dimensions[1]	45 gas passages, 40 feet high, 14 feet deep/chamber	Unchanged
Inlet Field Plate Area[1]	50,400 ft^2	Unchanged
Inlet Field Electrodes[1]	Wheelabrator bed frame "Star" Electrodes	Unchanged

[1]The inlet ESP field was left in place. The design is the original configuration as installed in 1975. It is not the intention to operate the inlet field, however it was left in place as an added benefit of the system.

2.1.2 Bag Layout

The following is a description of the number and type of bags in the system. Some plugging of bags may occur, but in general, this should be an accurate description of the system with regards to filtration distribution. A diagram of the bag layout is included in Appendix B23.

Table 4 Bag Layout and Type Description (Prior to June Boiler wash outage)

Compartment	Number of Bags	Bag Type
Chamber 1A Field 2	100/313	GORE-TEX™ Felt/GORE-TEX™ Membrane /Cond. PPS Felt/ GORE-TEX™ Membrane
Chamber 1A Field 3	413	PPS Felt/GORE-TEX™ Membrane
Chamber 1A Field 4	413	PPS Felt/GORE-TEX™ Membrane
Chamber 1B Field 2	392	GORE-TEX™ Felt/GORE-TEX™ Membrane
Chamber 1B Field 3	392	Washed GORE-TEX™ Felt/GORE-TEX™ Membrane (originally installed 10/2002)
Chamber 1B Field 4	393	NOMEX felt/PTFE membrane
Chamber 2A Field 2	81/312	GORE-TEX™ Felt/GORE-TEX™ Membrane /Cond. PPS Felt/ GORE-TEX™ Membrane
Chamber 2A Field 3	393	GORE-TEX™ Felt/GORE-TEX™ Membrane
Chamber 2A Field 4	393	Washed GORE-TEX™ Felt/GORE-TEX™ Membrane (originally installed 10/2002)
Chamber 2B Field 2	413	GORE-TEX™ Felt/GORE-TEX™ Membrane
Chamber 2B Field 3	413	Cond. PPS Felt/ GORE-TEX™ Membrane
Chamber 2B Field 4	413	P-84 felt/PTFE Membrane

Table 5 Bag Layout and Type Description (After June Boiler wash outage)

Compartment	Number of Bags	Bag Type
Chamber 1A Field 2	100/313	GORE-TEX™ Felt/GORE-TEX™ Membrane / P-84 felt/PTFE Membrane
Chamber 1A Field 3	413	P-84 felt/PTFE Membrane
Chamber 1A Field 4	413	P-84 felt/PTFE Membrane
Chamber 1B Field 2	392	GORE-TEX™ Felt/GORE-TEX™ Membrane
Chamber 1B Field 3	392	Washed GORE-TEX™ Felt/GORE-TEX™ Membrane (originally installed 10/2002)
Chamber 1B Field 4	393	NOMEX felt/PTFE membrane
Chamber 2A Field 2	81/312	GORE-TEX™ Felt/GORE-TEX™ Membrane / P-84 felt/PTFE Membrane
Chamber 2A Field 3	393	GORE-TEX™ Felt/GORE-TEX™ Membrane
Chamber 2A Field 4	393	Washed GORE-TEX™ Felt/GORE-TEX™ Membrane (originally installed 10/2002)
Chamber 2B Field 2	413	GORE-TEX™ Felt/GORE-TEX™ Membrane
Chamber 2B Field 3	413	P-84 felt/PTFE Membrane
Chamber 2B Field 4	413	P-84 felt/PTFE Membrane

2.2 Dependent Characteristics

2.2.1 Dependent Data

The dependent data is largely presented in graphical format in the Appendix. The specific data points that are instrumented and presented are as follows;

Plant Gross Load: Continuously monitored TDC-3000 calculated value based on the generator output voltage and current. When the plant trips offline or shuts down for maintenance, the plant gross load will be zero.

Total Flue Gas Flow: Continuously monitored using United Science Inc.'s Ultra Flow 100 ultrasonic flow monitor. The flow monitor is located at the stack midlevel (see position #6 on the figure in 2.2.2). The readout of the flow monitor is in kscfm using 68^{o}F and 29.92 in HG as standard conditions. The flow is converted to kacfm using the following equation:

$$\text{Gas Flow (kacfm)} = \frac{(\text{Gas Flow(kscfm)}*(460 + \text{Inlet Gas Temp}^{o}\,\text{F})}{(460+68^{o}\,\text{F})} * \frac{29.92 \text{ in HG}}{(28.56 \text{ in HG} + \text{AHPC outlet Pressure})}$$

Inlet Flue Gas Temperature: Continuously monitored using a grid of Type E thermocouples. The thermocouples are located at the AHPC inlet (see position #1 on the figure in 2.2.2). There are eight thermocouples at the inlet of each of the four AHPC chambers for a total of 32 thermocouples.

Tubesheet Differential Pressure: Continuously monitored on two of the twelve compartments. Pressure taps above and below the tubesheet (see positions #3 and #4 on the figure in 2.2.2) are equipped with Honeywell 3000 Smart DP Transmitters.

Flange–Flange Differential Pressure: Continuously monitored using two Honeywell 3000 Smart DP Transmitters at the AHPC inlet (see position # 2 in the figure in 2.2.2) and two Honeywell 3000 Smart DP Transmitters at the AHPC outlet (see position #5 on Diagram 1). Continuously calculated by the TDC- 3000 by taking the difference between the flue gas pressure at the AHPC inlet and outlet.

Air-to-Cloth Ratio: Calculated by dividing the Gas Flow (acfm) by the total surface area of the bags.

Opacity: Continuously measured by the plant opacity monitor, Monitor Labs Model #LS541. Opacity is measured in the Plant Stack, position 6 on the figure in 2.2.2. Position 6 is approximately at the 300 ft. level from grade.

Flue Gas Outlet Pressure: Continuously monitored using two Honeywell 3000 Smart DP Transmitters at the AHPC outlet (see position #5 in the figure in 2.2.2). The inlet pressure can be determined by the difference between the outlet pressure, and the flange-to-flange pressure drop.

Temperature per Chamber: See Inlet Temperature above.

ESP Power Consumption: Continuously monitored with a watt-hour meter to each chamber.

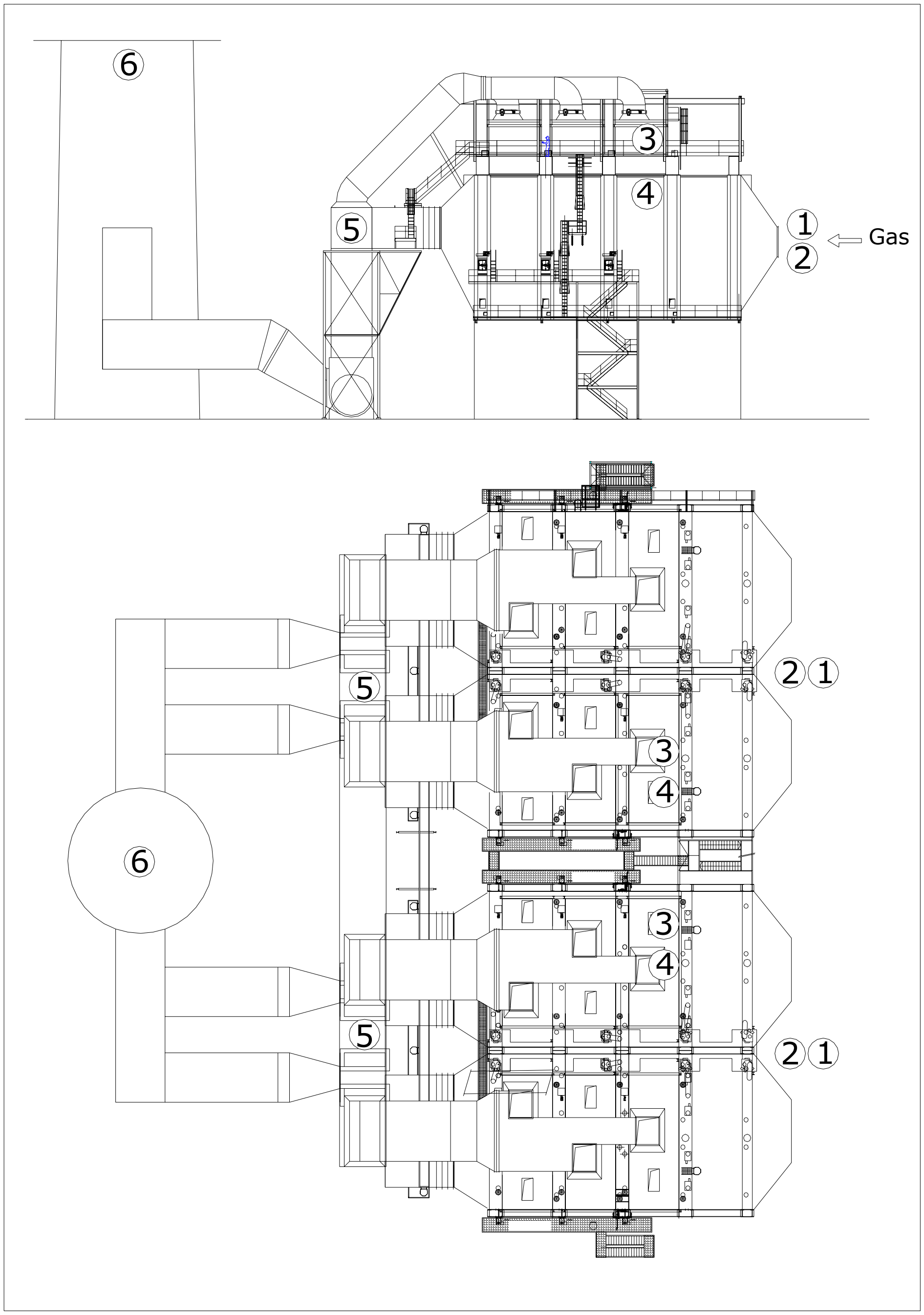
Compressed Air Flow: Continuously monitored using a Diamond II Annubar flow sensor equipped with a Honeywell 3000 Smart DP Transmitter. This ANNUBAR instrument is in the compressed air supply line after the compressors but before the desiccant dryer.

The non-instrumented data that can be found in the appendix is as follows

- Coal Analysis
- Flyash Analysis
- Coal and Alternative fuel Burned

2.2.2 Instrument Location Diagram

1 & 2: Advanced Hybrid Inlet
3 & 4: Above and Below Tubesheet
5: Advanced Hybrid Outlet
6: Plant Stack



2.2.3 Data Retrieval

Big Stone Plant's Honeywell TDC-3000 process control system monitors and controls a large number of actuators, sensors, and processes using PID controllers, programmable logic controllers, and special-purpose programs. Data gathered by the TDC-3000 is retrieved using an existing plant historian database. The dependent characteristic data presented in this report is calculated using 60-minute averages of the TDC-3000 readings, which are recorded every minute.

2.2.4 Data Reduction

Reported NO_X and SO_2 emissions have had 5% of data removed due to erroneous spikes occurring during daily calibration of CEMS instrumentation. No other assumptions or restrictions were used to transform the raw measured data into a form usable for interpretation.

3.0 RESULTS AND DISCUSSION

3.1 General Results and Discussion

3.1.1 Chronological History of Significant Accomplishments

<u>Quarter 1 (October 2002 – December 2002)</u>	
System Startup	October 2002
Rapper Problems Realized	November 2002
Pulse Valve Problems Realized	November 2002
EERC Testing (99.99% particulate capture goal met)	November 2002
Inlet Field Energized	December 2002
<u>Quarter 2 (January 2003 – March 2003)</u>	
Soybeans burned at Big Stone as Alternative Fuels	January 2003
Derates due to high dP across the AH system begin	January 2003
Comparative Testing of Pilot unit to full-scale unit	February 2003
Plant shut down to wash boiler	February 2003
<u>Quarter 3 (April 2003 – June 2003)</u>	
Meeting to discuss improvement options	April 2003
Bags washed in two chambers	April/May 2003
Pitot data used for evaluation and decision	May 2003
Decision to replace filter bags	May 2003
Complete bag changeout	June 2003
Inlet field evaluated	June 2003
Plant restored to full load	June 2003
<u>Quarter 4 (July 2003 – September 2003)</u>	
Big Stone limited to 440 – 445 MW not due to AH	July/Sept 2003
Performance Tests	July/Sept 2003
Fluent Analysis Plan	Sept 2003
Preliminary baffle design submitted	Sept 2003
<u>Quarter 5 (October 2003 – December 2003)</u>	
Opacity rise attributed to initiation of bag failures	October 2003
Competitive bidding of replacement bags	November 2003
Fluent modeling results for flow baffles	November 2003
Test flow baffles installed	December 2003
Four compartments of bags replaced	December 2003
<u>Quarter 6 (January 2004 – March 2004)</u>	
Stable system operation	Jan/March 2004
Fluent modeling work continues	February 2004
Technology goals reviewed	February 2004
Next phase of project reviewed & proposed by OTP	March 2004

Quarter 7 (April 2004 – June 2004)

PPS Bags Failing and Opacity Rising	April/June 2004
Inlet Field AH Proposal	May 2004
All PPS Bags replaced with P-84 Bags	June 2004
Chamber 2B baffles installed	June 2004
One compartment of blowpipes modified	June 2004
Opacity returned to low levels	June 2004
Bag analysis performed	June 2004
Additional 8 bags removed for testing	June 2004

3.1.2 Discussion of Results of Significant Accomplishments

General Discussion

Operation of the Advanced Hybrid has been fairly stable. There have been no significant derates of the power plant due to Advanced Hybrid system. The remaining PPS bags have begun to fail at an unacceptable rate, and it was a good decision to plan on replacing all of the PPS bags during the scheduled June shut down. The major activities of this quarter were;

- Work related to the boiler wash outage including;
  - Replacement of 1928 PPS filter bags with P-84/BHATex filter bags.
  - One complete chamber of Baffles installed
  - One compartment of blowpipes modified
  - 10 filter bags pulled and sent to independent laboratory for analysis
- Review of proposed design for installation of AH components in the inlet field
- Bag testing data reviewed

June Boiler Wash Outage

The plant was shut down from June 5th to June 12th for the scheduled boiler wash. During this period, Southern Environmental Inc. was contracted to come in and perform the tasks listed above. A complete report of these activities can be found in Appendix 24.

Overall, the work that was completed was done well and on-time. It appears that our choice of using the P-84 bag from BHA was a good one and will hopefully get us through the warm summer temperatures without premature bag failures.

Proposed Project for Installation of Advanced Hybrid components in inlet field

A meeting between OTP, EERC, and SEI was held at the Big Stone Plant on Friday, March 5, 2004. The purpose of the meeting was to discuss the bid requirements and design optimization for the following items:

1. Manufacture and install 1 Chamber of bag row baffles in June 2004
2. Modify one compartment of blowpipes in June 2004
3. Convert 4 inlet ESP fields into Advanced Hybrid compartments in April 2005
4. Include with item 3, installing ESP field below new AH compartments
5. Design and construct new AH chamber for construction in April 2005

An engineering review meeting was held at SEI headquarters on April 13-14. The bag row baffle design and blowpipe modifications for the June 2004 outage were finalized. SEI also presented their progress on the items 3-5 above. Main items of discussion were:

1. Changing the plate-to-plate spacing from 12 in. to 10 in.
    - This closer spacing allows for more rows of bags thus lowering the A:C
    - This will not degrade the ESP performance
2. Determining the maximum number of bags per compartment
    - Four additional rows of bags will be added in each compartment
    - Total of 1974 additional bags representing a 41% increase in filtration surface area
3. Extending the length and increasing the number of the electrodes and plates
    - Rigid electrodes and collecting plates will be lengthened from 25 feet to 37 feet creating an ESP collecting zone below the fabric filter components
    - Below the level of the bag row baffles, the collecting plates will be solid instead of perforated.
    - There will be no discharge electrodes in the gas passages below the filter bags
    - The area below the pulse headers will be filled from the hot roof to the top of the hoppers with new discharge electrodes and solid collecting plates
4. Rapping systems
    - Electromagnetic rappers will be used instead of tumbling hammers for the discharge electrodes
    - The drive from the existing collecting plate tumbling hammer rapper system will be relocated and reused.
5. Duct work tie in
    - Outlet ductwork from new inlet compartment will tie straight into the outlet duct from field two
6. Electrical & controls
    - Discussed cable splicing options and Hesch pulse controller capabilities to handle additional compartments
7. New compartments include bag row baffles and modified blowpipe design

A brief discussion was held concerning the design and construction of a new AH chamber. Few details were discussed as converting the inlet fields to Advanced Hybrid was agreed upon as the most economical performance improvement option.

Following this meeting, a purchase order was issued to SEI for bag row baffles in one chamber and modification of the blowpipes in one compartment. Both of which took place during the June 2004 outage. SEI has also submitted a firm bid to convert the inlet ESP fields into the Advanced Hybrid as discussed above. The quote for $3,625,000, would not include, filter bags, taxes, baffles or blowpipe modifications for the remaining compartments, or any additional costs as a result of NETL participation (EERC testing and reporting). They have requested a letter of intent and partial purchase order from OTP to begin engineering no later than August 1, 2004 to ensure construction readiness in April 2005.

<u>Bag Testing Data</u>

A significant amount of bag testing data was reviewed this quarter. The entire report by W.L. Gore and Associates is included in the appendix. The summary table from that report is included below.

Otter Tail Power Company
Big Stone Power Plant Improvement Initiative Demonstration Site
Filter Bag analysis summary chart - All Frazier #'s are reported as cfm/ft2@0.5 in.w.g. driving force

Location	Service Time	Max. exposed temp (F)	Backing	As rec'd (F-n)	Mullen Burst (psi)	Mullen Burst % Strength Retention	Tensile strength - cross machine direction (psi)	%Tensile strength retention - cmd	Tensile strength - machine direction (psi)	% Tensile strength retention - md	Comments
1BF3 R1B1	6/10/03 to 9/17/03	365	all PPS	2.9	249	72	113	39	83	61	membrane OK, tan felt color
1BF3 R1B3	"	365	all PPS	3.6	226	66					membrane cracking along some of the vertical cage wires
1BF3R1B4	"	365	all PPS	4	223	65					membrane cracking at vertical/horizontal cage wire junctures
1BF3 R1B6	"	365	all PPS	3.8	182	53			51	37	membrane delaminated during HEC cleaning
1BF3R1B7	"	365	all PPS	2.7	236	69	114	39	61	45	membrane cracking, tan felt color
2BF2 R3B5	"	500	all GT	1.9	717	100					membrane OK
2BF2 R3B8	"	500	all GT	1.5	735	100					membrane OK
2BF3 R19B6	"	500	cond PPS	2.3	481	96	181	54	243	100	membrane OK, chocalat brown felt color
2BF3 R19B7	"	500	cond PPS	2.2	473	94	180	54	200	83	bag turned inside out during removal
2BF4 R20B7	"	500	all PPS	2.8	208	60	90	31	73	53	membrane scraped during removal, dark tan felt color
1AF4 R11B11	6/10/03 to 9/27/03	322	all PPS	3.9	234	68	123	43	90	66	membrane cracking along vertical and horizontal cage wires
1AF4 R1B20	6/10/03 to 10/24/03	322	all PPS	3.6	368	78	104	36	42	31	membrane cracking in vertical direction between vertical cage wires
1AF4 R1B12	"	322	all PPS	4	229	67	73	25	24	17	membrane cracking at vertical/horizontal cage wire junctures, tan felt color
1BF3 R21B5	"	365	all PPS	6.9	203	59	48	16	10	8	holes formed through felt backer, choc. brown felt
1BF3 R21B6	"	365	all PPS	5	210	61	33	11	2	2	membrane delamination, holes in felt
2AF4 R21B14	"	450	cond PPS	2	463	92	115	34	197	82	tan discoloration, hole in felt
1AF2 R15B11	6/10/03 to 2/28/04	322	cond PPS	2.6	449	89	224	67	205	85	membrane OK
1AF3 R11B15	"	322	all PPS	3	214	59	125	43	78	57	holes formed at vertical/horizontal cage wire junctures
2AF4 R13B10	12/3/03 to 2/28/04	350	SUPERFLEX	3.5	870	100	483	100	405	100	membrane OK
2AF4 R13B9	"	350	Fiberglass	3.1	920	100	729	100	461	100	membrane OK, small areas scraped during removal
2BF4 R11B6	"	365	P-84	5.1	337		185		97		membrane delamination throughout entire length of bag
	new	80	NOMEX	5.4	513		408		160		brand new
			new all PPS		366		289		137		
			cond PPS		503		337		241		
			all GT		650						

The overall conclusions in the report from W.L. Gore and Associates are as follows:

Conclusions:

- GORE-NO STAT® filter bags continue to maintain excellent membrane integrity and physical strength.

- Laboratory analysis of the filter bags revealed no membrane damage caused by electrostatic discharge or sparking.

- After 10 weeks of service SUPERFLEX® and fiberglass backed filter bags exhibited no loss in physical strength and membrane integrity.

- The all PPS backed and conductive PPS backed GORE-TEX® membrane filter bags have shown they are sensitive to temperature upsets.

- Future physical strength analysis should include Tensile strength testing, preferably using the Instron instrument.

®GORE-TEX and GORE-NO STAT are registered trademarks of W. L. Gore & Associates, Inc.

As the power plant operator, we consider the information in this light, 'What bag should be installed in the system to give a balance of low resistance to gas flow and strength retention in service for prolonged mechanical life?'. With the operation results of the all PPS bags unacceptable with regards to mechanical bag life, it seems that our options looking ahead for filter bag backing are as follows (each of these bags would likely include a PTFE membrane);

- PTFE
- Superflex
- Fiberglass
- P-84
- NOMEX

At this time, it has not been determined which bag is the most likely candidate to give a good balance of performance. Additional testing and operation time is needed. Factors such as the Frazier number, as well as percentage strength retention need to be taken into account.

4.0 CONCLUSIONS

The four fundamental performance parameters of the Advanced Hybrid system are;

- Opacity (Appendix B8)
- Air-to-cloth ratio (Appendix B7)
- Tubesheet dP (Appendix B5)
- Compressed air flow (Appendix B22)

Opacity has risen significantly during this quarter of operation. The continued failure of the all PPS bags is quite evident. It was a good decision to plan on replacing all of the PPS bag material during the scheduled wash outage in June. After the bags were replaced, the opacity has returned to historically low levels, and visually, the stack looks very clean. We should be near the previously tested high particulate capture rate.

The A/C ratio has been reduced slightly during this quarter, as the plant load demand has dropped. This is likely due to very temperate ambient conditions and the reduction of customer demand.

The tubesheet dP has remained controllable, with the trigger point at 8.25 – 8.5 INH2O. The period after startup until the end of June the average dP was less than 8.0 INH2O.

Prior to the wash outage, the compressed air flow was fluctuating between 1000 and 2000 acfm depending on load demands. After the outage in June, the demand was as low as has been historically seen, with the usage approximately 250 acfm. This reduction in compressed air usage is largely due to the slightly lower loading of the plant due to reduced energy demand of the electric grid. This usage will undoubtedly increase significantly during the next quarter of operation.

<u>General Conclusions</u>

A lot of information was gathered and activities taken place during this quarter. There was a significant bag changeout in June, in which 1,928 PPS bags were removed from the system and replaced with P-84 bags. There are now no PPS bags in service, and a determination of the most advantageous bag will need to be made as we move ahead.

The effort for an additional project to install improved Advanced Hybrid components and lower the A/C ratio is underway. It was estimated that the NETL would need at least two months to review a proposal for additional compartments to be installed in the inlet field. The equipment supplier advised the team that engineering work needed to start by August 1, 2004, to make a delivery and installation date of April 15, 2005. This means that the proposal to the NETL needed to be submitted by June 1, 2004 to be seriously considered. As of June 30, 2004, this was not submitted to the NETL.

The significant issues next quarter to report will likely be:

- Measurable results of baffle installation
- Measurable results of pulse pipe modifications
- Bag life through the warm summer months
- A decision on whether or not to install improved additional Advanced Hybrid components in the inlet field in April 2005.

5.0 APPENDICES

APPENDIX A - COMMENTS ON ANOMALIES OF GRAPHICAL DATA

Appendix B5 & B6. The initial dP data was not historized correctly, so the first couple of days of dP history do not exist in the Plant Historian.

Appendix B19. Significant increases in Chamber Power typically indicate periods where the initial inlet field was energized, although spikes also occur during periods of reduced loading on the unit.

Appendix B17. Right hand column of units is incorrect. The ug/g unit is correct, but this is not a direct percent.

Appendix B8. Opacity Graph shows two spikes in the opacity reading that were not real (1/15/2003 & 3/1/2003). These spikes were instrumentation failures and/or calibrations.

Appendix B8. Opacity graph shows spikes around 6/10/2003. These are instrument difficulties, and not representative of actual opacity.

Appendix B15. bam, ebm, etc. are Powder River Basin mine codes

Appendix B14 & 15. The "adjustment" refers to an end of the month correction based on a comparison between visual levels and bookkeeping levels.

Appendix B21. Pulse counter graph seems to indicate no pulsing after the June 12, 2003 startup until the end of June. However, the scale is so large and the pulse cycle frequency was so insignificant, that it cannot be seen as a clear increase until the next quarter. The number of pulse cycles by June 30,2003 was 284.

Appendix B2, B3 & B7. Low stack flow readings around 7/21/2003 are instrument problems and not real readings. As can be seen in B1, the plant was on-line and operating during the indicated period of no flow.

Appendix B8. Opacity spikes around 7/21/2003 and 9/23/2003 are instrument problems and not representative of actual high opacity.

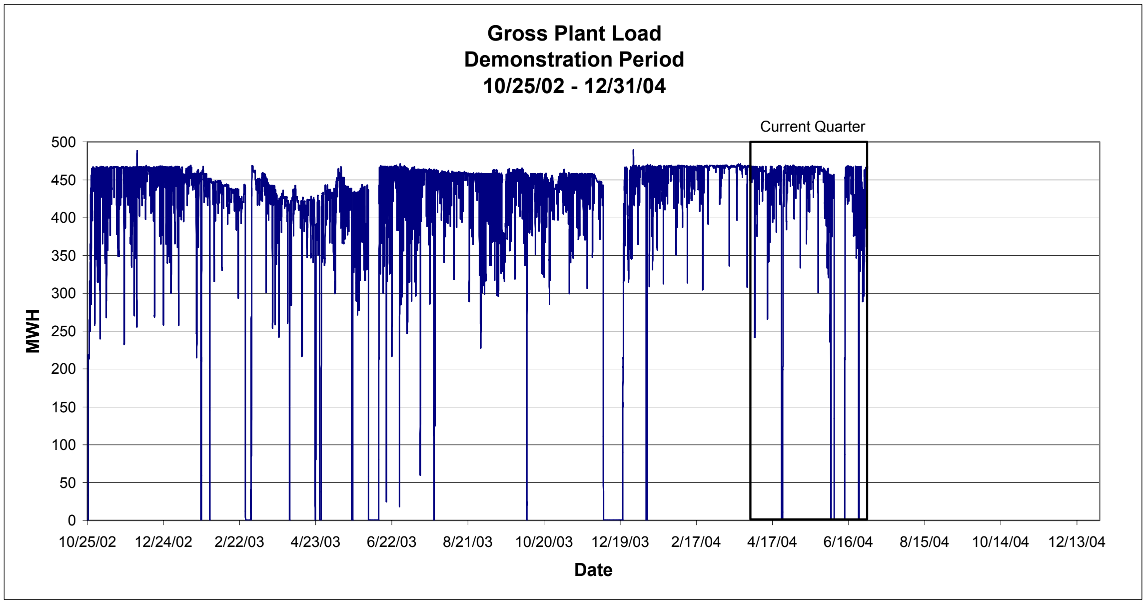
Appendix B8. During the plant outage, (the period represented approximately 12/4/2003 – 12/9/2003 on the graph), the opacity is out of scale because it was removed from the plant stack and a "clear stack" calibration was performed in a clean environment. So the data from that period is not valid.

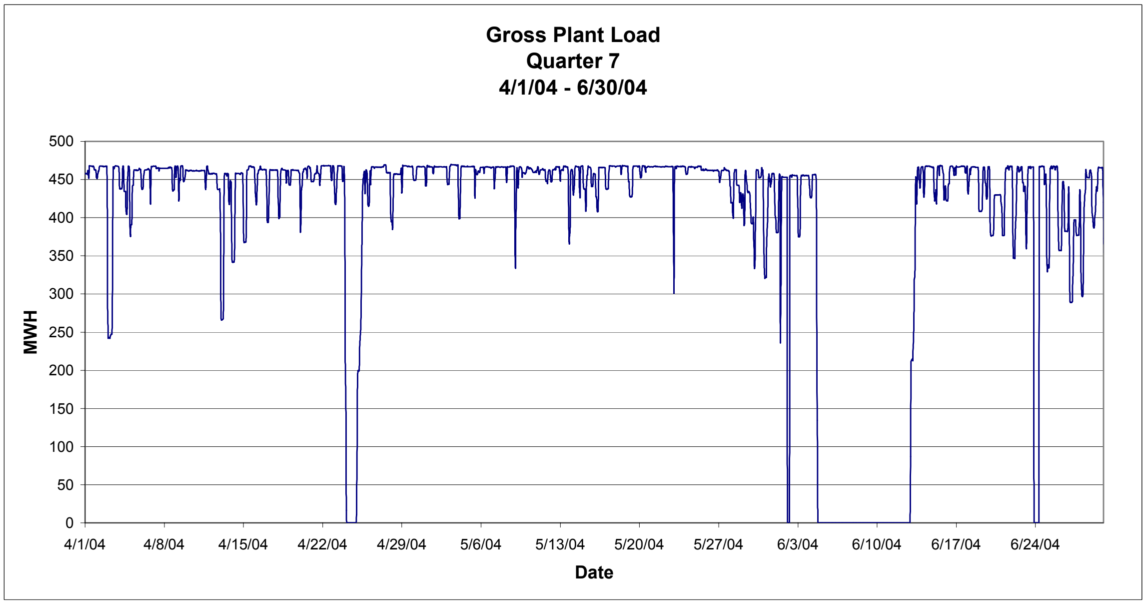
Appendix B6. There is no clear reason for the high differential pressure reading around 3/3/2003.

Appendix B8. The Opacity spike around 3/25/2005 was due to a calibration, and not a real opacity event. The step change in opacity can be attributed to a calibration issue and not a real opacity event.

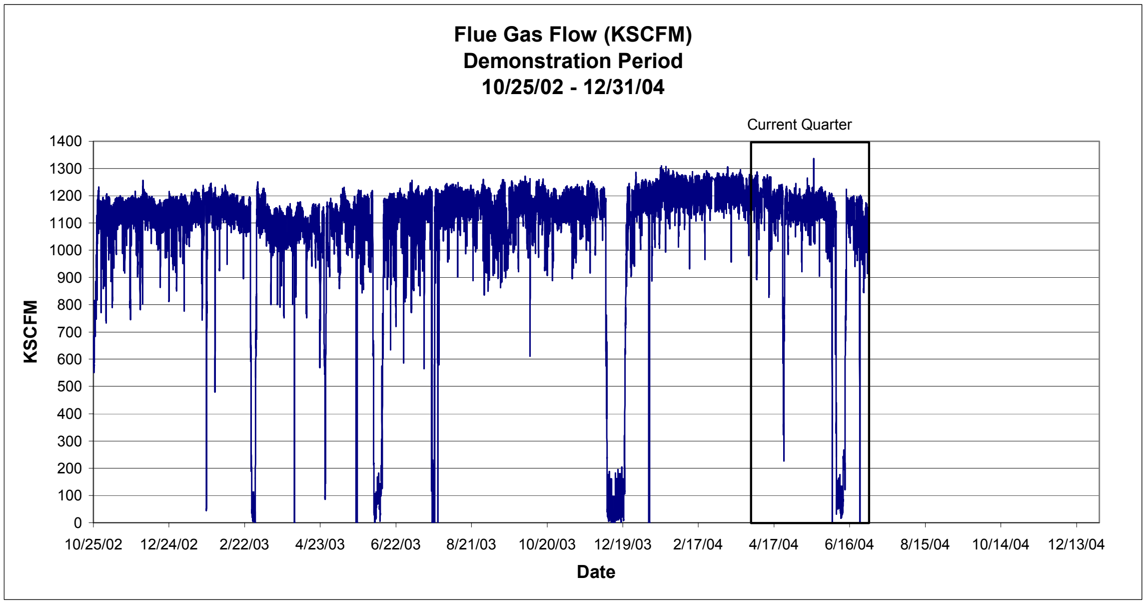
APPENDIX B – GRAPHICAL & TABULAR PERFORMANCE DATA

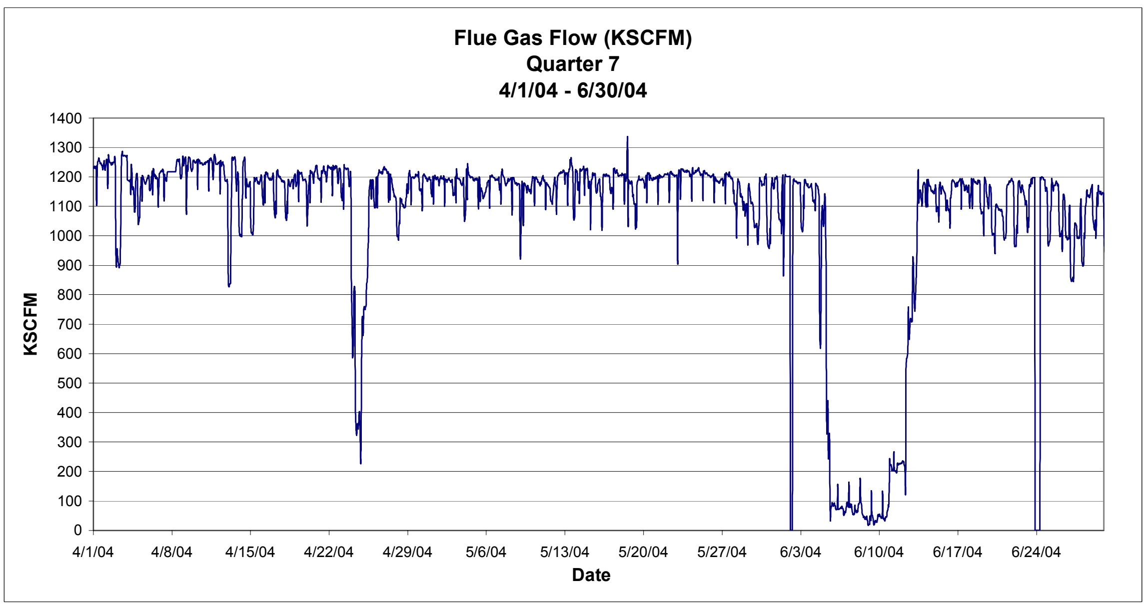
B1 Gross Plant Load



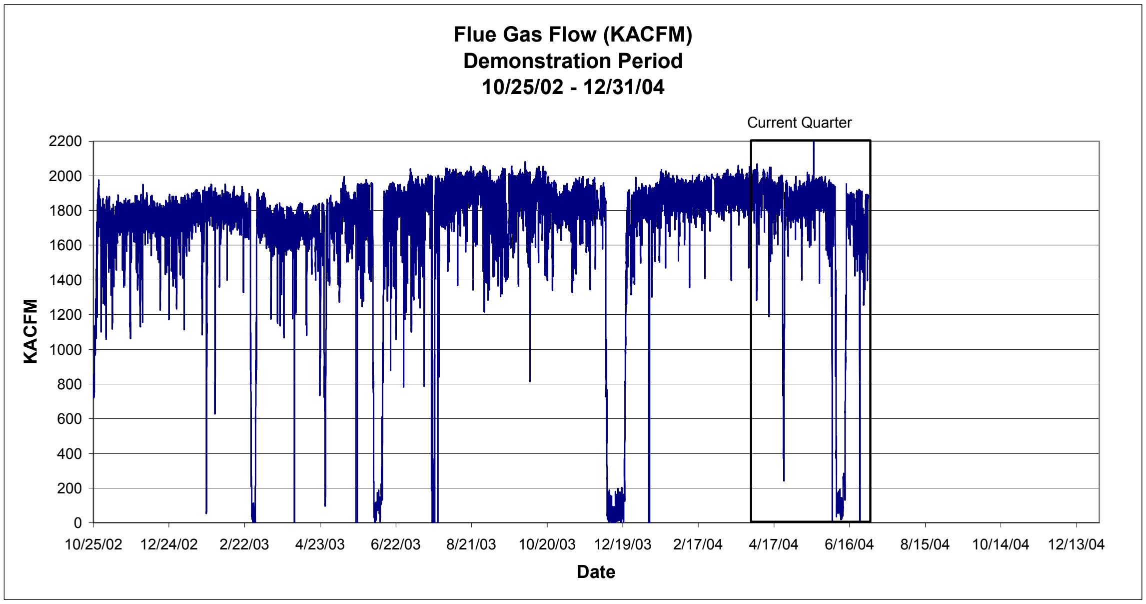


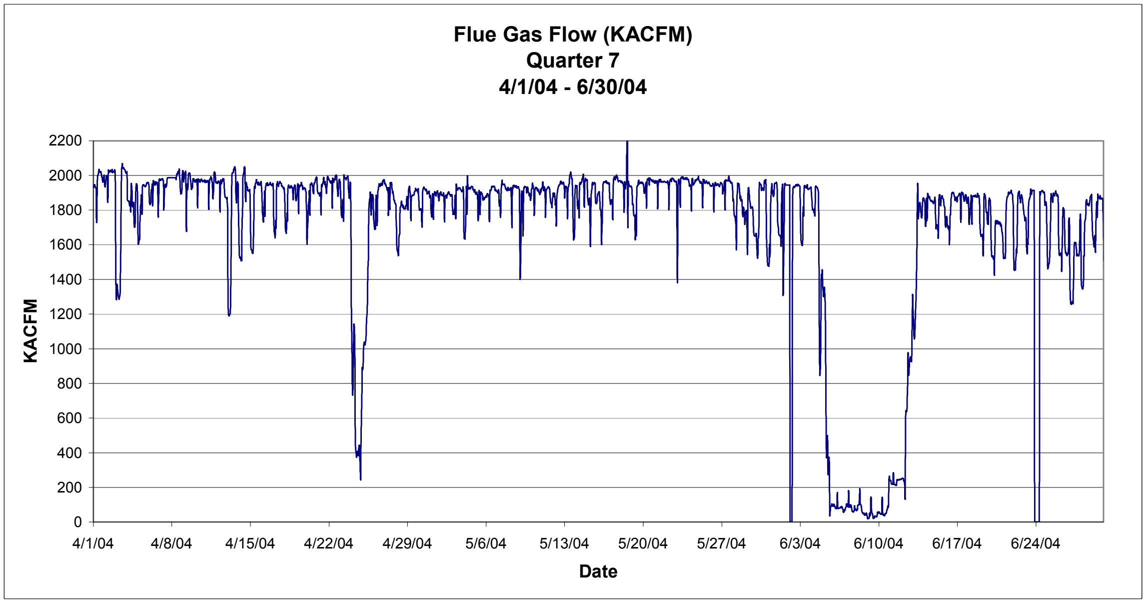
B2 Flue Gas Flow (KSCFM)



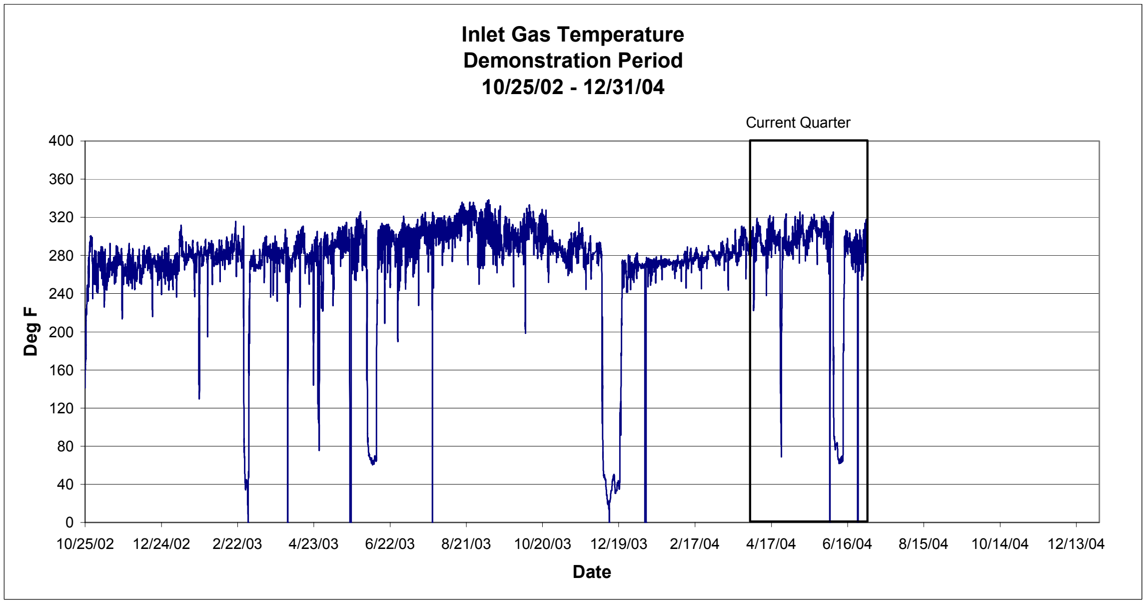


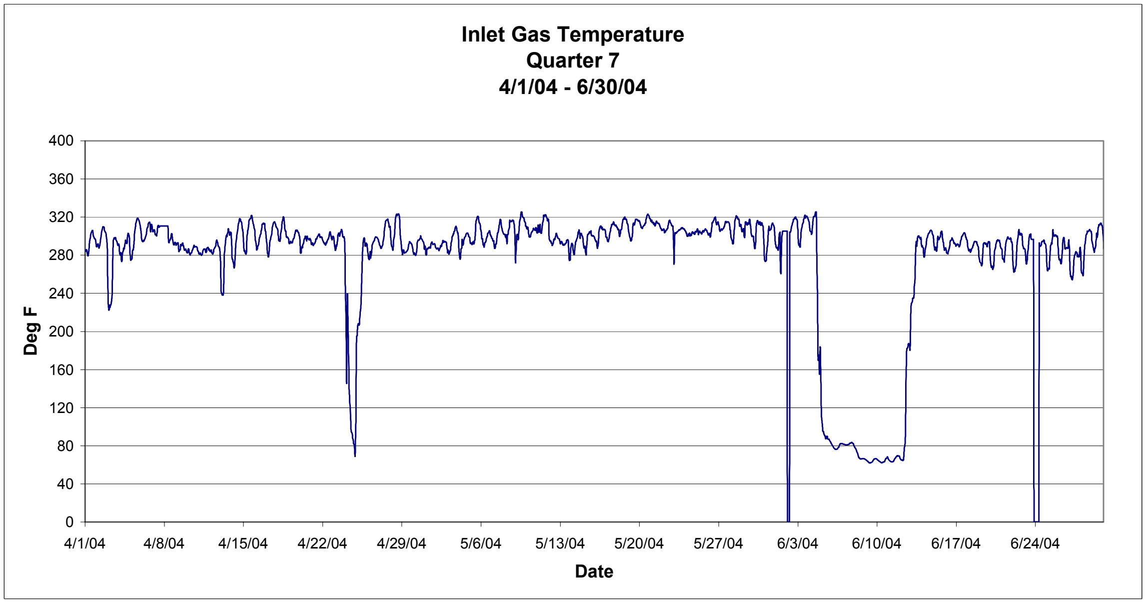
B3 Flue Gas Flow (KACFM)



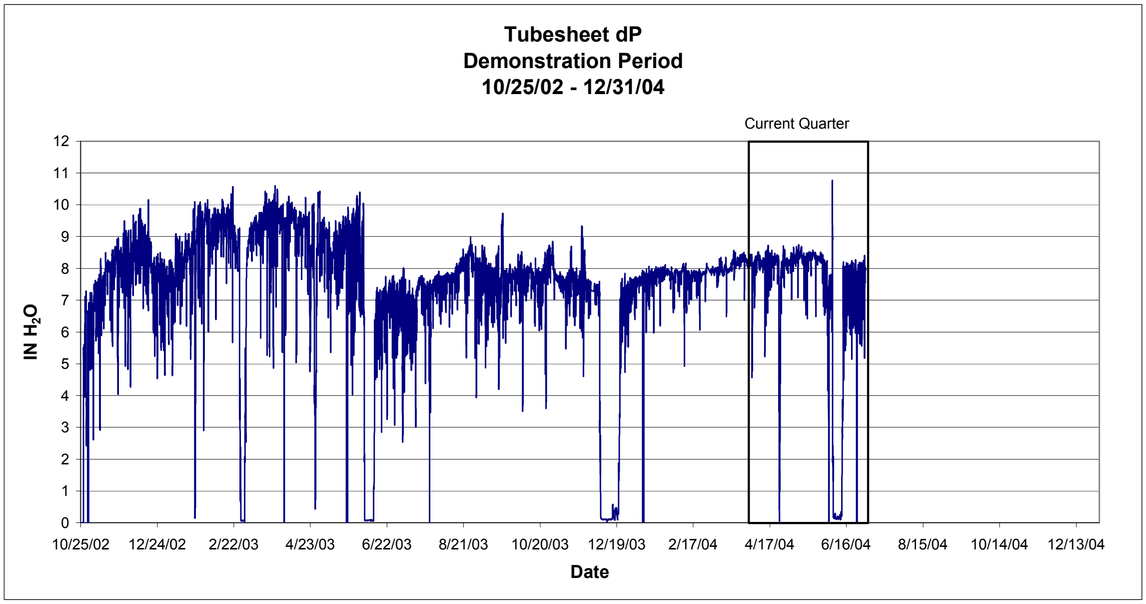


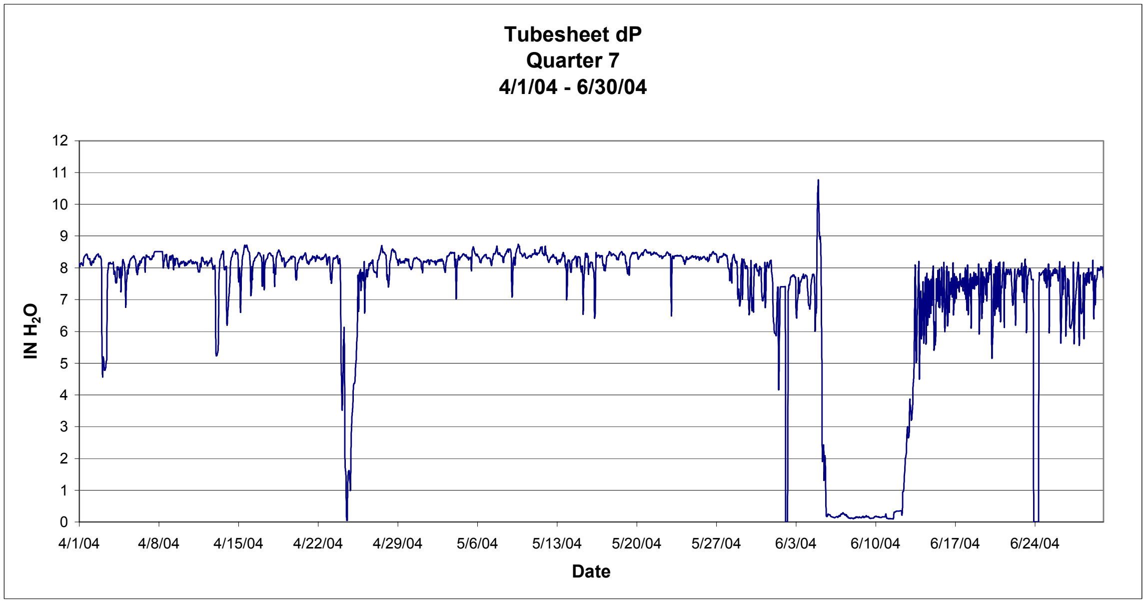
B4 Inlet Gas Temperature



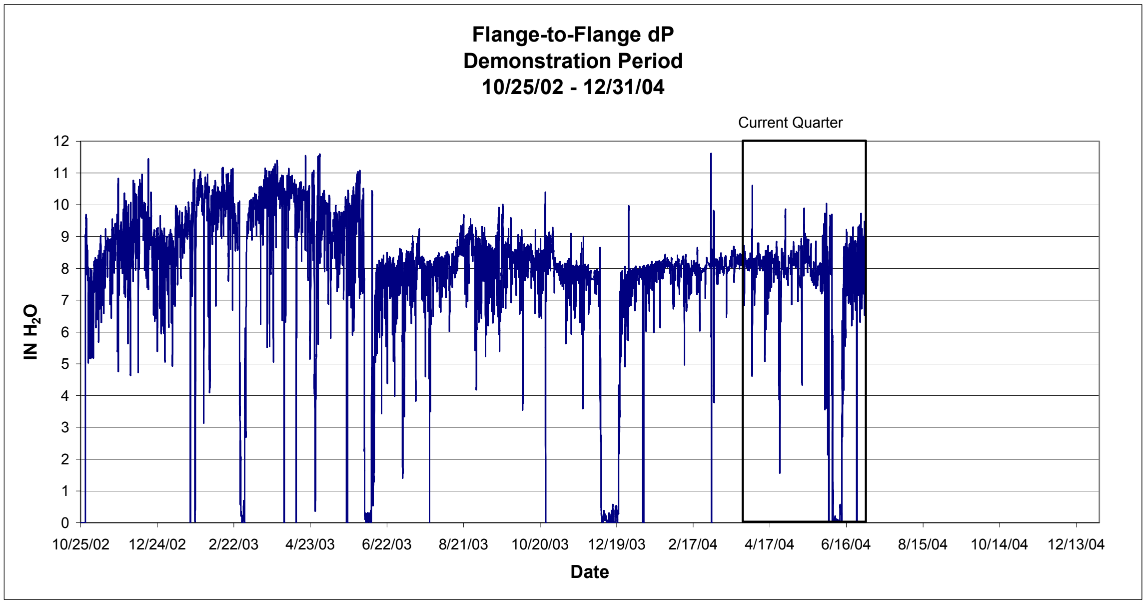


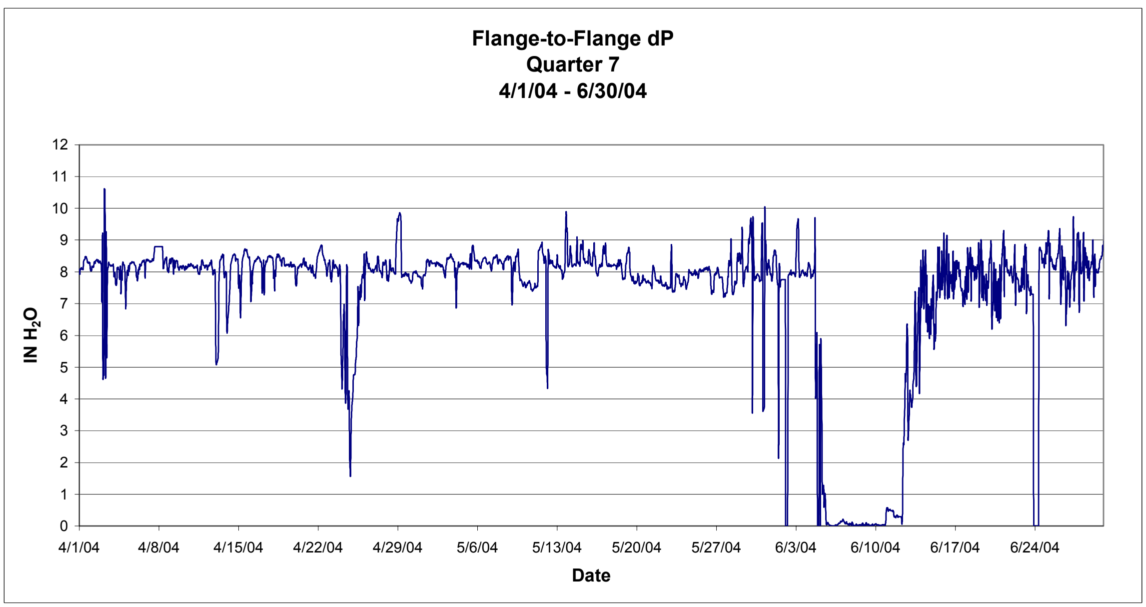
B5 Tubesheet dP



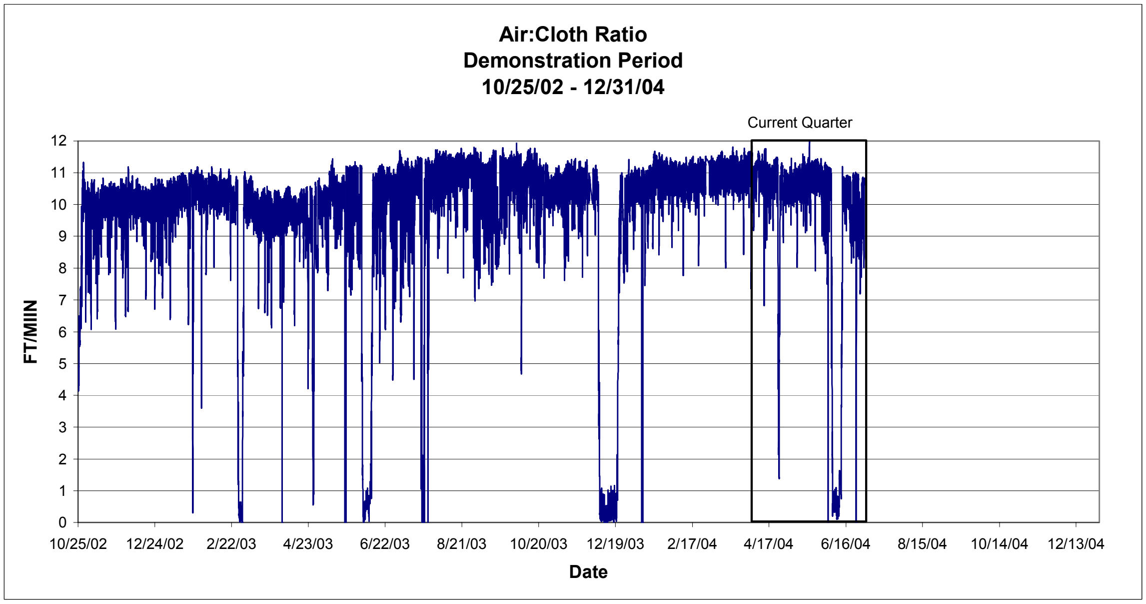


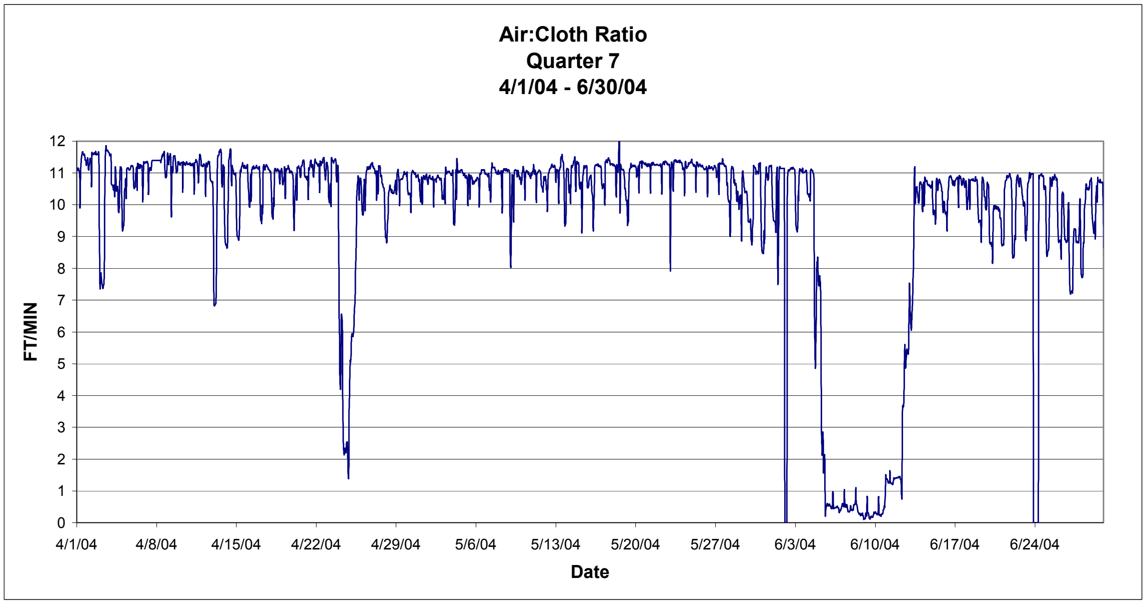
B6 Flange-to-Flange dP



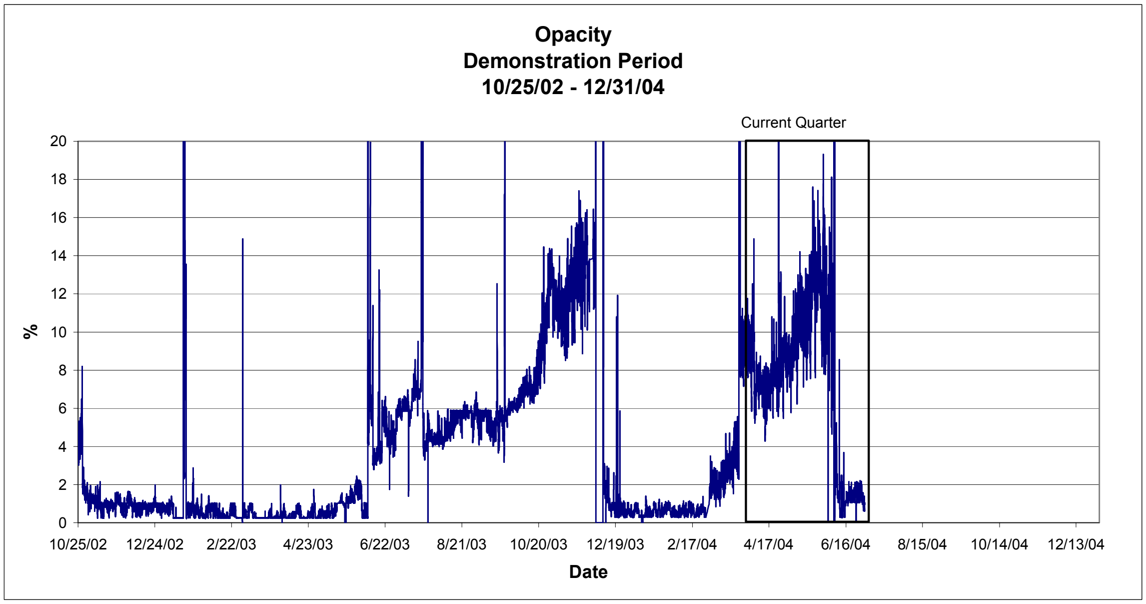


B7 Air-to-Cloth Ratio

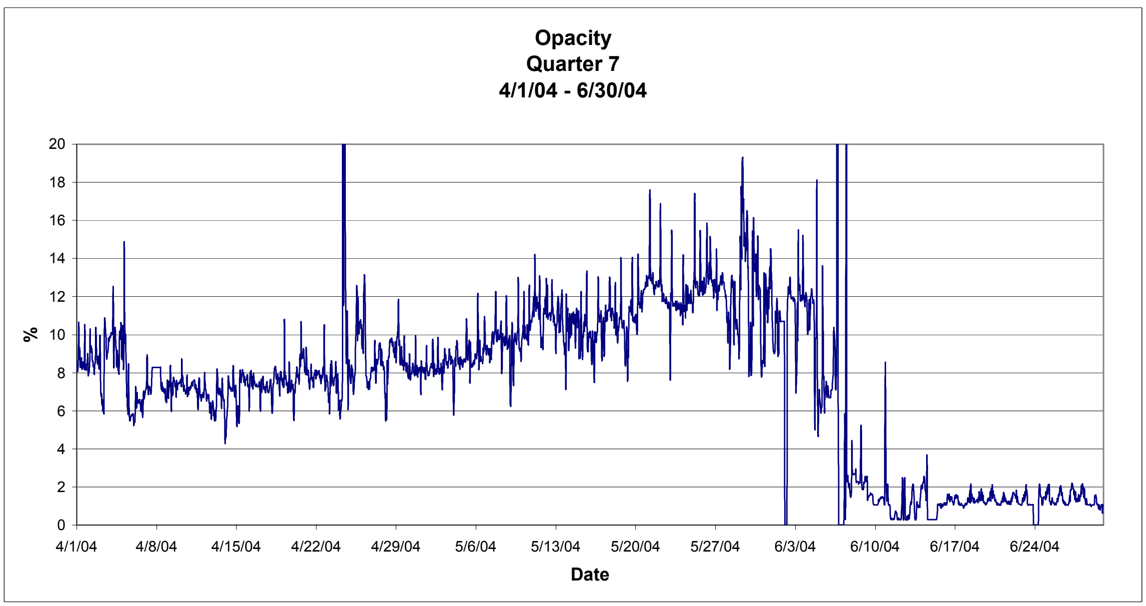




B8 Opacity

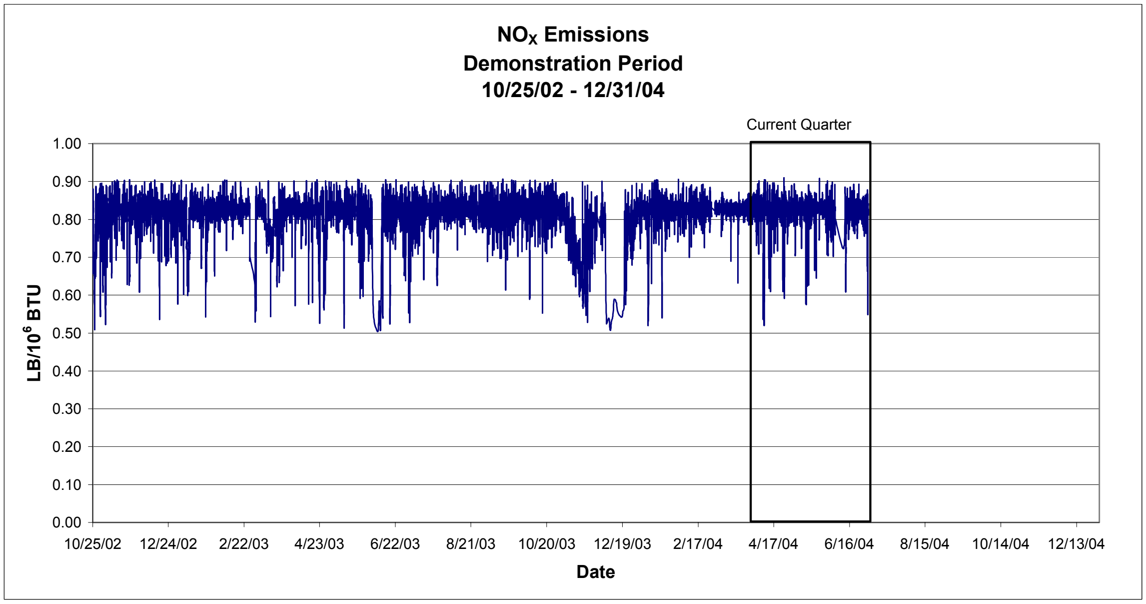


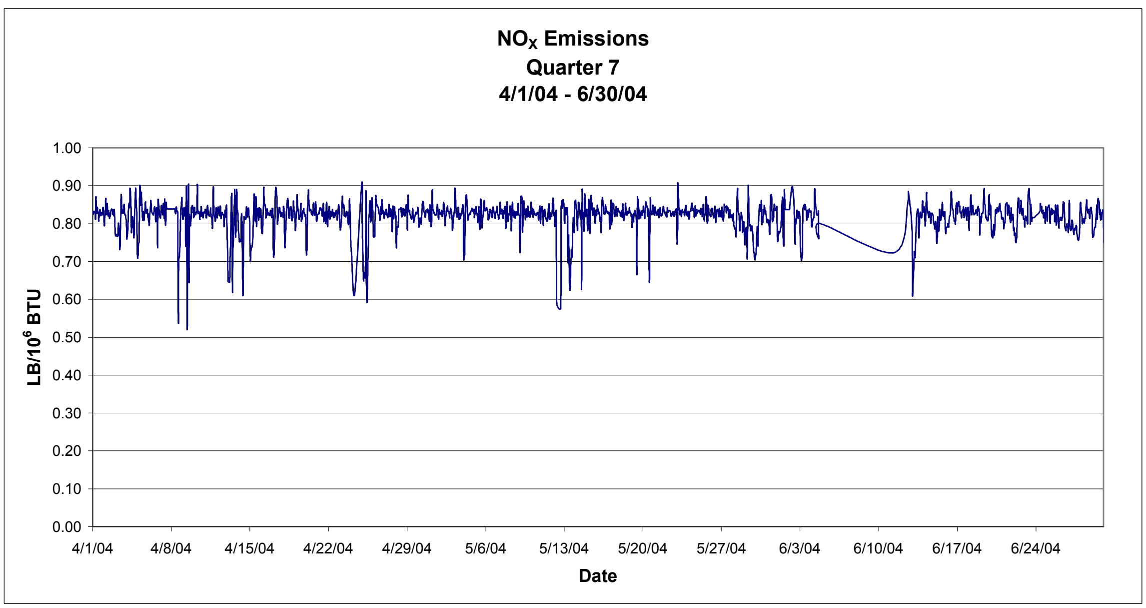
Opacity
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
%
20
18
16
14
12
10
8
6
4
2
0
10/25/02
12/24/02
2/22/03
4/23/03
6/22/03
8/21/03
10/20/03
12/19/03
2/17/04
4/17/04
6/16/04
8/15/04
10/14/04
12/13/04
Date



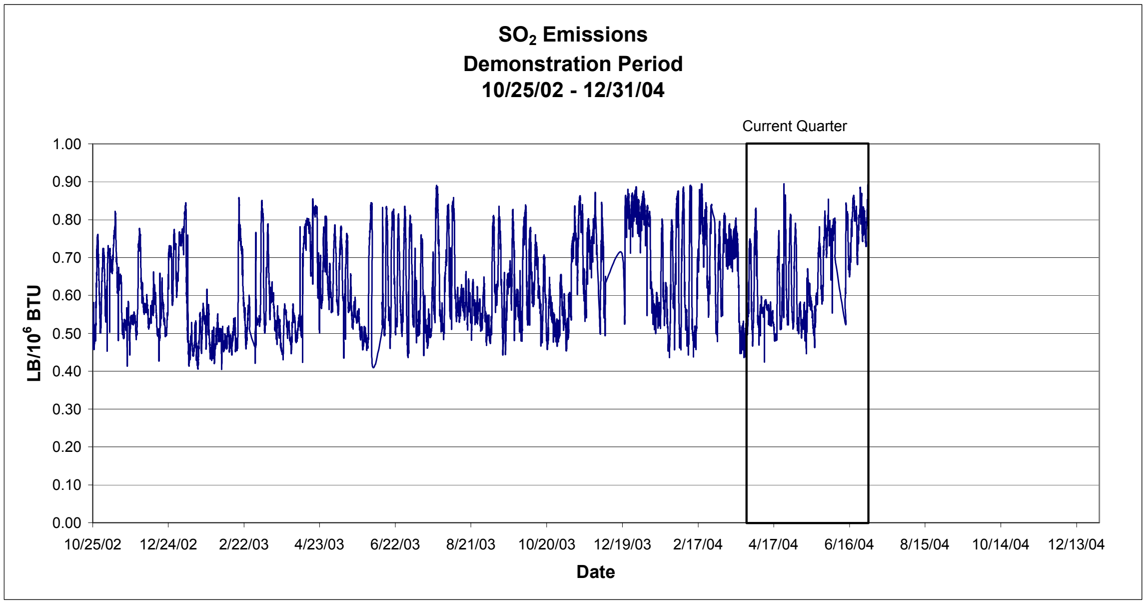
Opacity
Quarter 7
4/1/04 - 6/30/04
%
20
18
16
14
12
10
8
6
4
2
0
4/1/04
4/8/04
4/15/04
4/22/04
4/29/04
5/6/04
5/13/04
5/20/04
5/27/04
6/3/04
6/10/04
6/17/04
6/24/04
Date

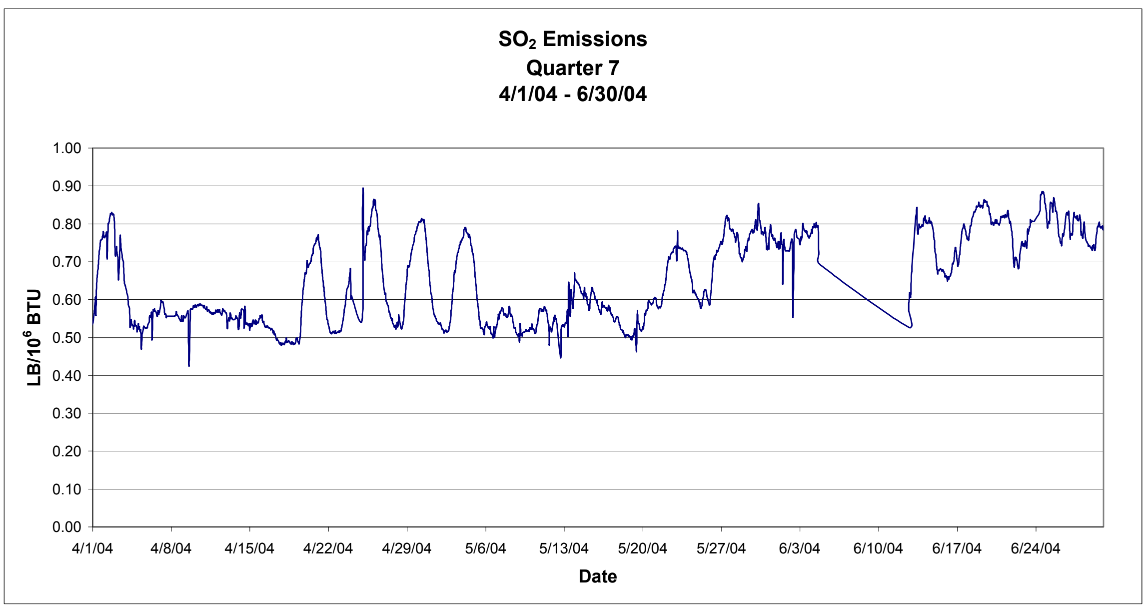
B9 NO_X Emissions



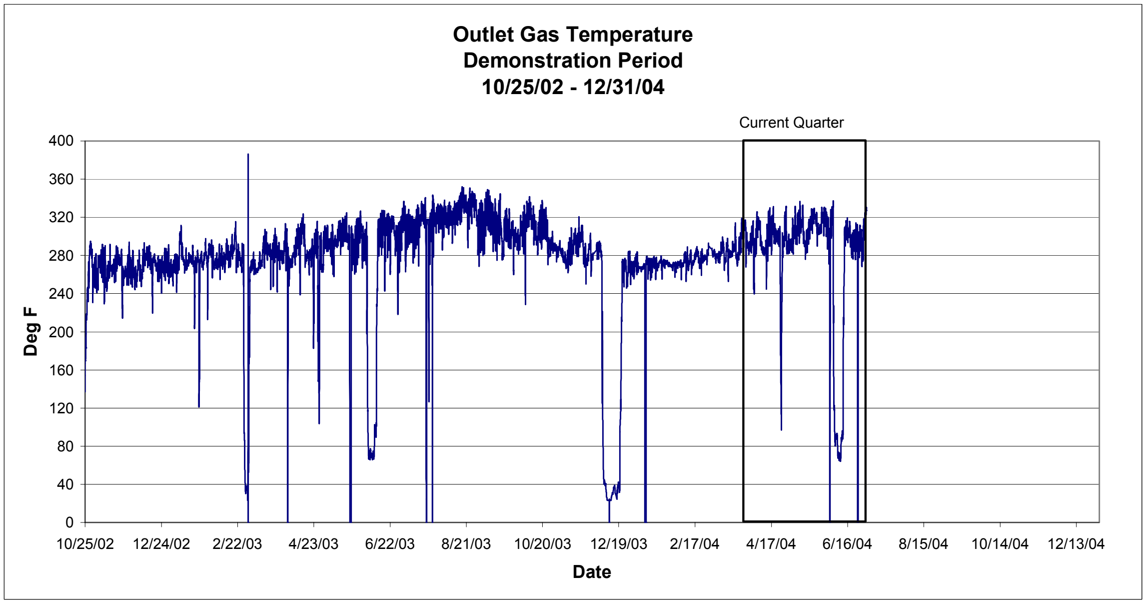


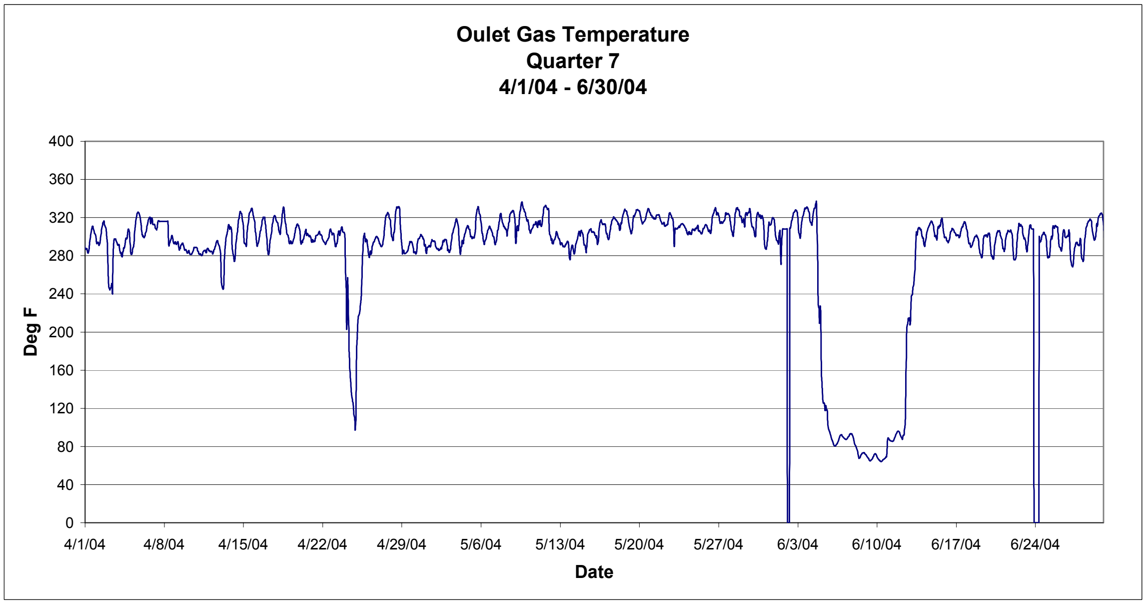
B10 SO_2 Emissions



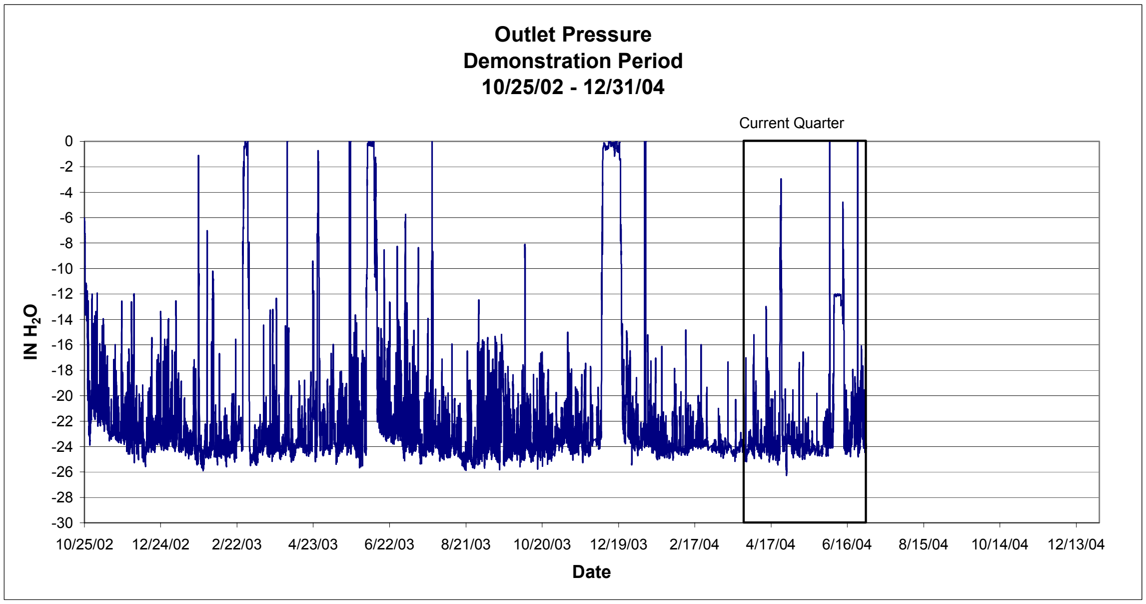


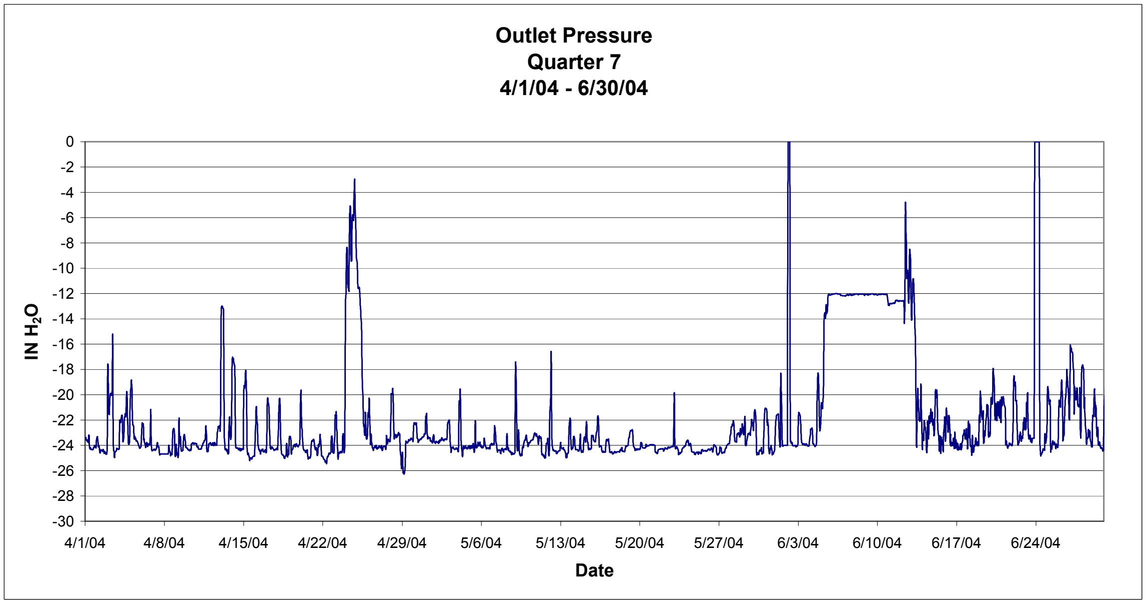
B11 Outlet Gas Temperature



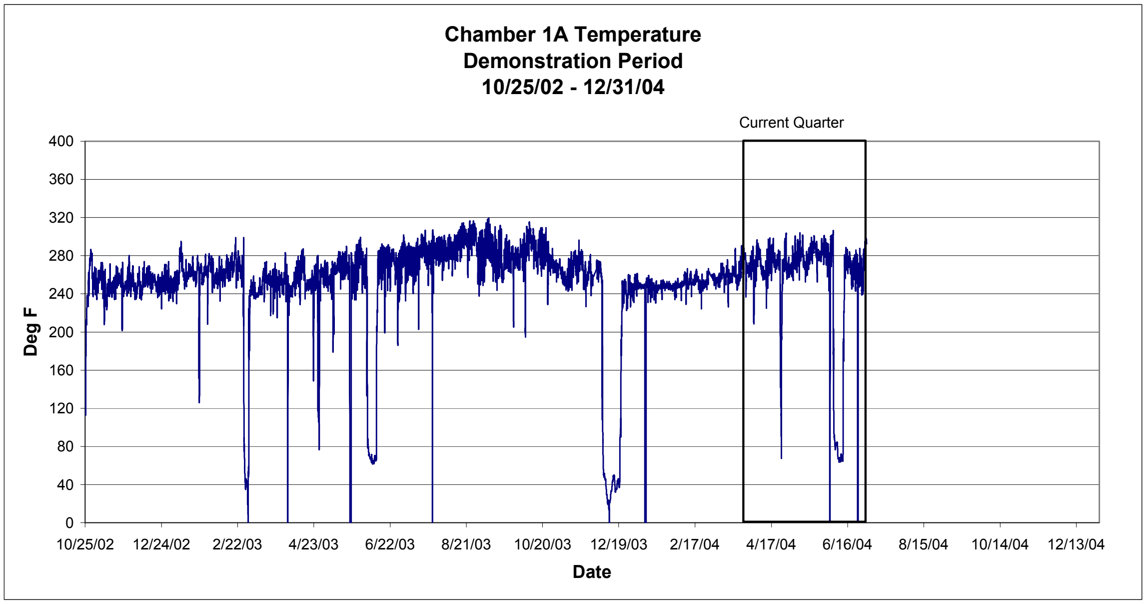


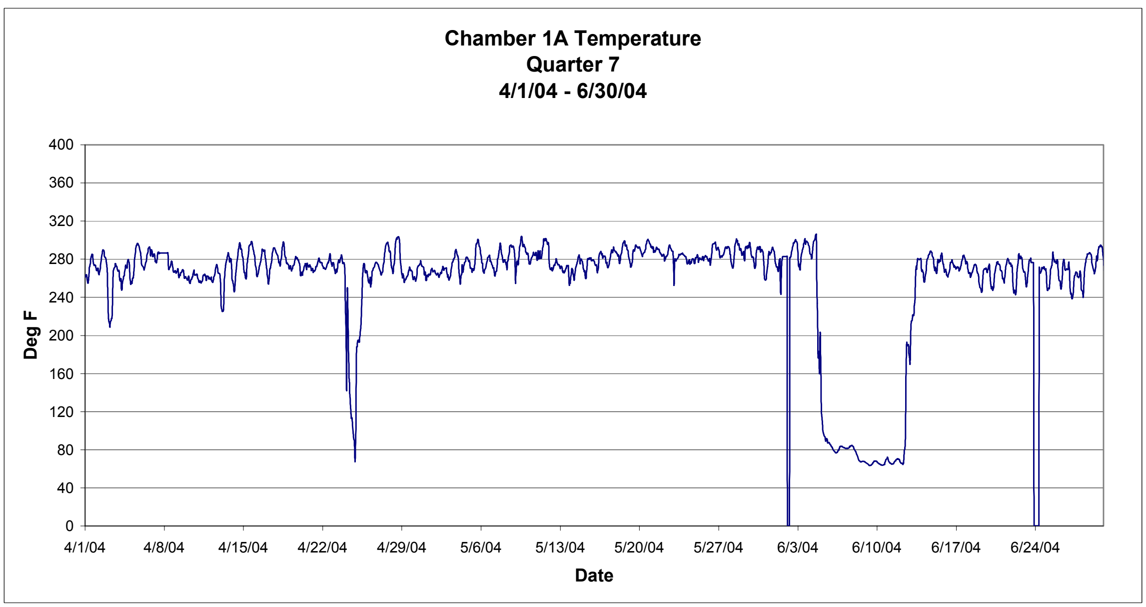
B12 Outlet Pressure

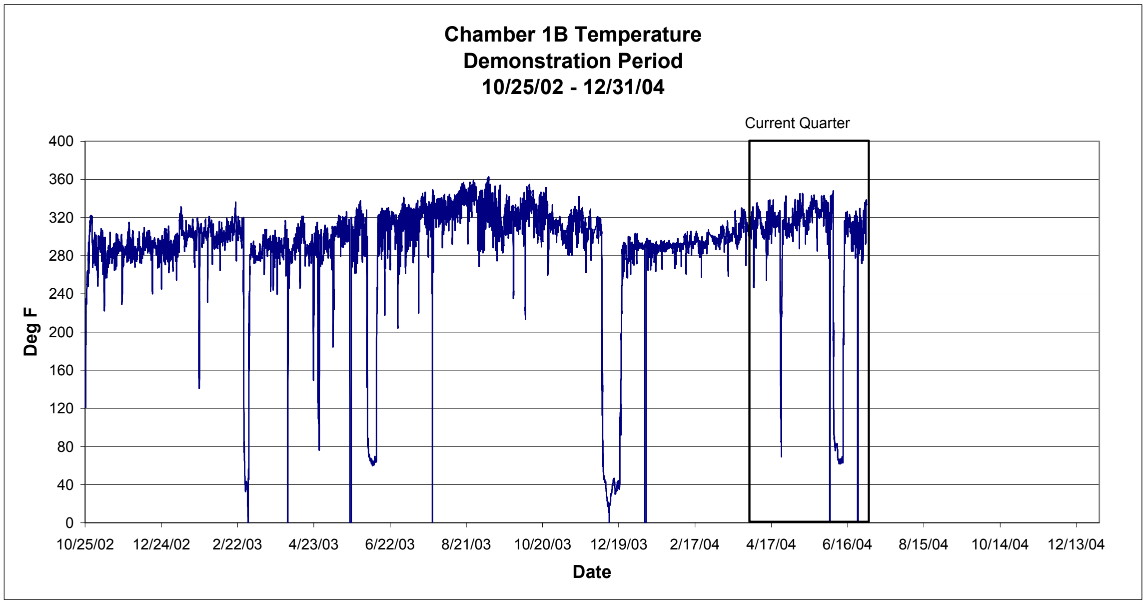


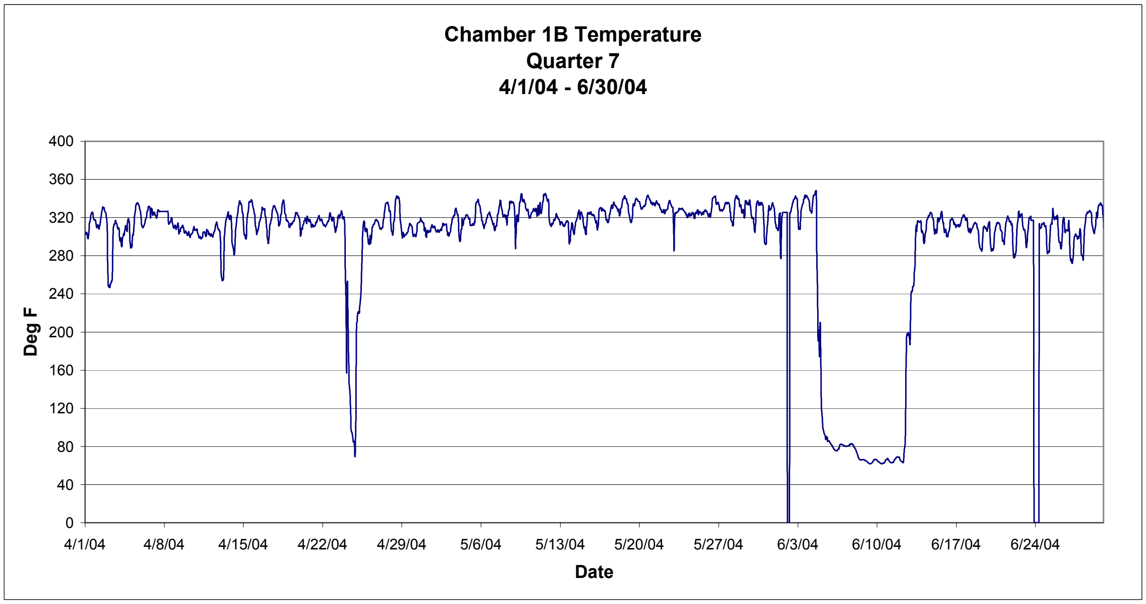


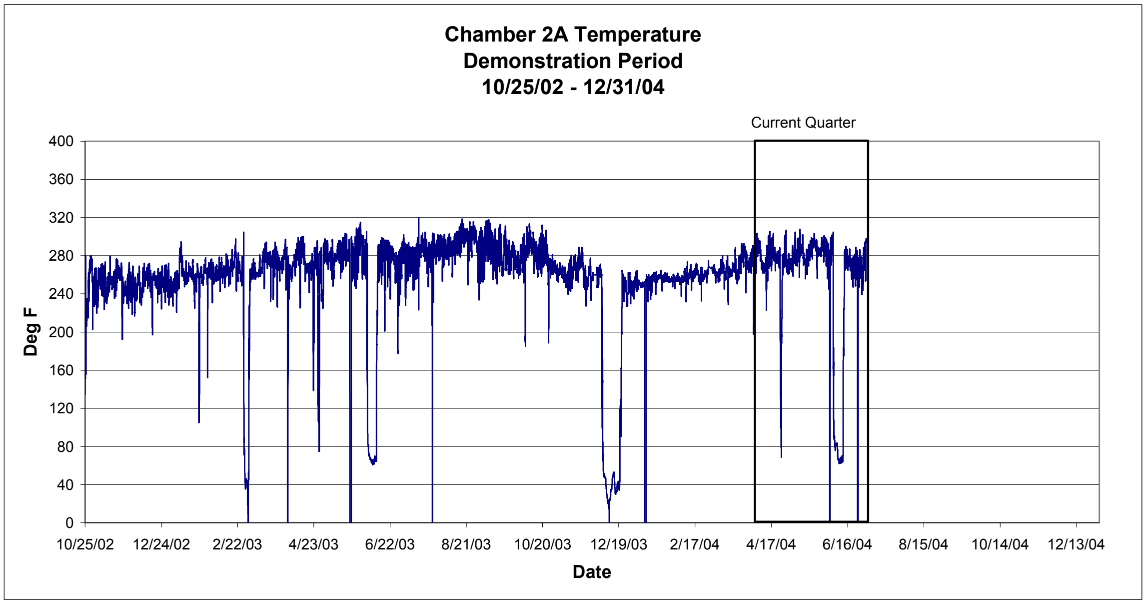
B13 Temperature per Chamber

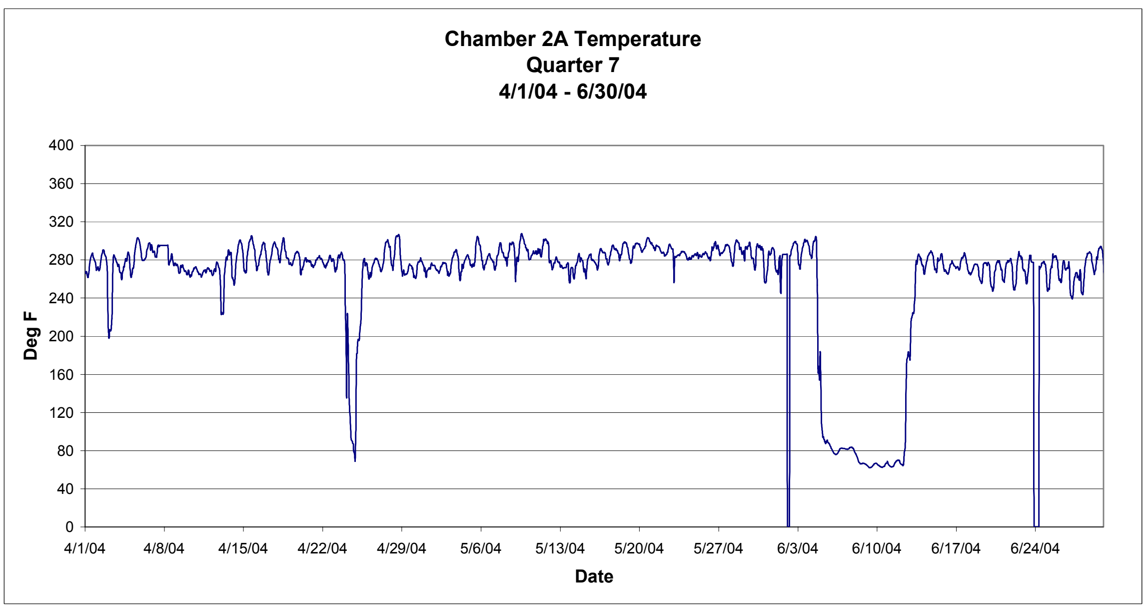


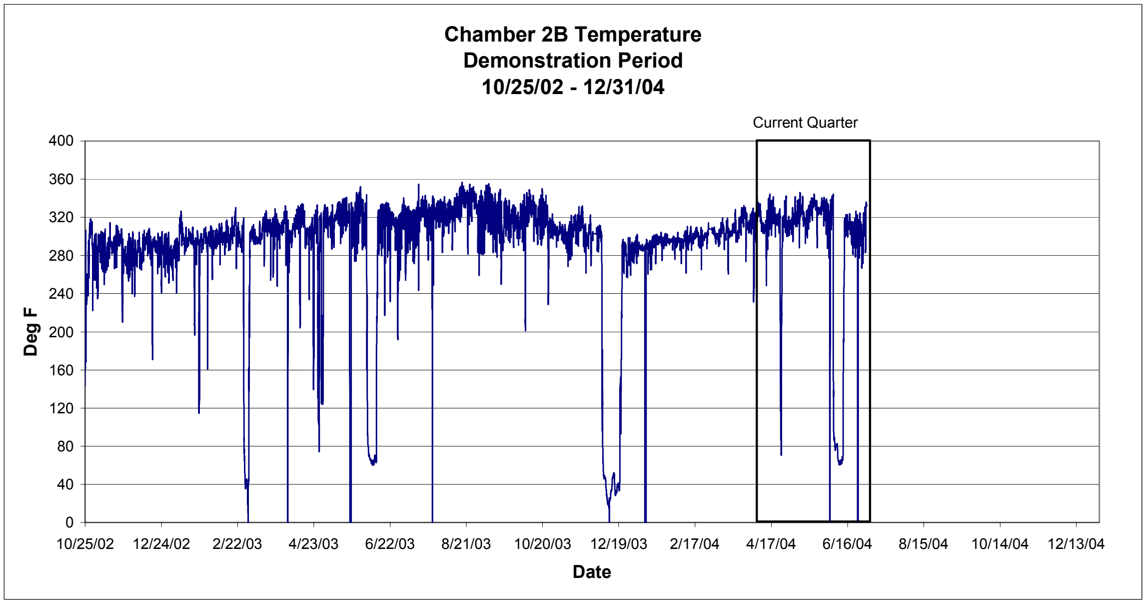


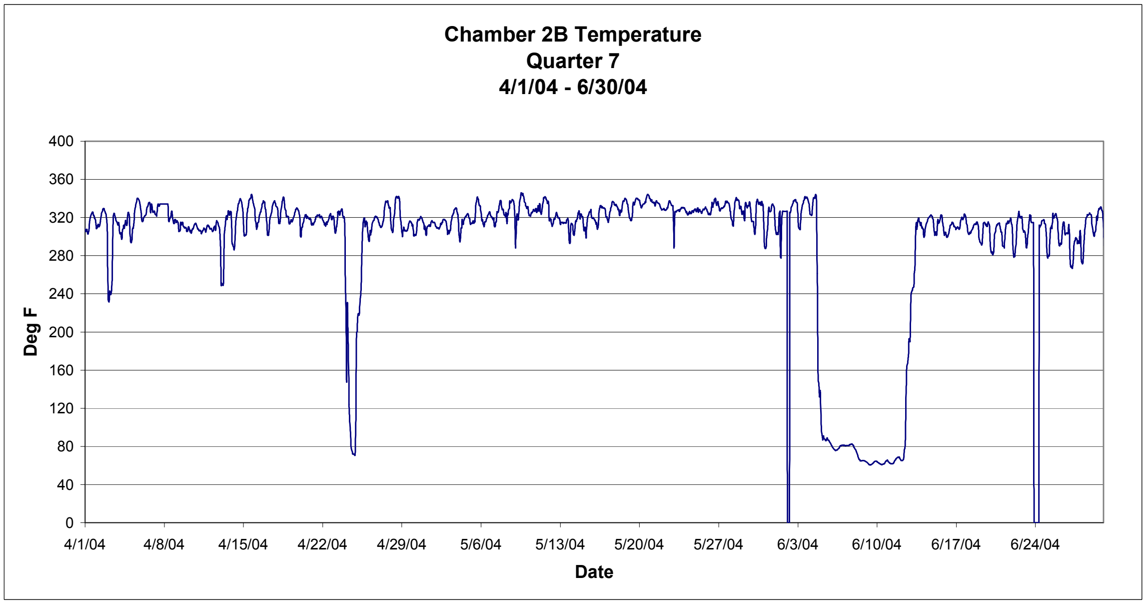

Chamber 1B Temperature
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
400
360
320
280
240
200
160
120
80
40
0
Deg F
10/25/02
12/24/02
2/22/03
4/23/03
6/22/03
8/21/03
10/20/03
12/19/03
2/17/04
4/17/04
6/16/04
8/15/04
10/14/04
12/13/04
Date


Chamber 1B Temperature
Quarter 7
4/1/04 - 6/30/04
400
360
320
280
240
200
160
120
80
40
0
Deg F
4/1/04
4/8/04
4/15/04
4/22/04
4/29/04
5/6/04
5/13/04
5/20/04
5/27/04
6/3/04
6/10/04
6/17/04
6/24/04
Date


Chamber 2A Temperature
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
Deg F
0
40
80
120
160
200
240
280
320
360
400
10/25/02
12/24/02
2/22/03
4/23/03
6/22/03
8/21/03
10/20/03
12/19/03
2/17/04
4/17/04
6/16/04
8/15/04
10/14/04
12/13/04
Date


Chamber 2A Temperature
Quarter 7
4/1/04 - 6/30/04
Deg F
0
40
80
120
160
200
240
280
320
360
400
4/1/04
4/8/04
4/15/04
4/22/04
4/29/04
5/6/04
5/13/04
5/20/04
5/27/04
6/3/04
6/10/04
6/17/04
6/24/04
Date


Chamber 2B Temperature
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
Deg F
400
360
320
280
240
200
160
120
80
40
0
10/25/02
12/24/02
2/22/03
4/23/03
6/22/03
8/21/03
10/20/03
12/19/03
2/17/04
4/17/04
6/16/04
8/15/04
10/14/04
12/13/04
Date


Chamber 2B Temperature
Quarter 7
4/1/04 - 6/30/04
Deg F
400
360
320
280
240
200
160
120
80
40
0
4/1/04
4/8/04
4/15/04
4/22/04
4/29/04
5/6/04
5/13/04
5/20/04
5/27/04
6/3/04
6/10/04
6/17/04
6/24/04
Date

B14 Fuel Burn Record

BIG STONE PLANT
FUEL BURN RECORD - page 1
Apr-04

DATE	Coal	P. Coke	TDF	Waste Seeds	Toner	Gran. Insul.	Canvas Belting	Plastic Chips
	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)
1-Apr-04	6,572.48	0.00	22.84	98.88	0.00	0.00	0.00	0.00
2-Apr-04	6,711.45	0.00	22.17	46.78	0.00	0.00	0.00	0.00
3-Apr-04	5,523.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-Apr-04	6,039.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-Apr-04	6,139.72	0.00	0.00	98.68	0.00	0.00	0.00	0.00
6-Apr-04	6,472.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7-Apr-04	6,481.63	0.00	22.40	119.97	0.00	0.00	0.00	0.00
8-Apr-04	6,613.32	0.00	0.00	95.68	0.00	0.00	0.00	0.00
9-Apr-04	6,665.89	0.00	0.00	26.51	0.00	0.00	0.00	0.00
10-Apr-04	6,709.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11-Apr-04	6,726.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12-Apr-04	6,358.18	0.00	0.00	97.32	0.00	0.00	0.00	0.00
13-Apr-04	5,728.55	0.00	0.00	93.85	0.00	0.00	0.00	0.00
14-Apr-04	6,138.60	0.00	0.00	49.20	0.00	0.00	0.00	0.00
15-Apr-04	6,302.95	0.00	22.39	24.06	0.00	0.00	0.00	0.00
16-Apr-04	6,532.74	0.00	0.00	50.06	0.00	0.00	0.00	0.00
17-Apr-04	6,463.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18-Apr-04	6,499.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19-Apr-04	6,689.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20-Apr-04	6,659.43	0.00	22.27	0.00	0.00	0.00	0.00	0.00
21-Apr-04	6,591.09	0.00	0.00	21.81	0.00	0.00	0.00	0.00
22-Apr-04	6,803.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23-Apr-04	6,680.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24-Apr-04	323.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25-Apr-04	5,039.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26-Apr-04	6,479.74	0.00	67.77	70.49	0.00	0.00	0.00	0.00
27-Apr-04	6,604.44	0.00	22.79	47.97	0.00	0.00	0.00	0.00
28-Apr-04	6,163.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29-Apr-04	6,644.04	0.00	0.00	15.36	0.00	0.00	0.00	0.00
30-Apr-04	6,537.30	0.00	0.00	24.30	0.00	0.00	0.00	0.00
Adjustment	0.00							
Total Burned	185,896.05	0.00	202.63	980.92	0.00	0.00	0.00	0.00
Total Delivered	196,186.76	0.00	202.63	980.92	0.00	0.00	0.00	0.00
HHV	8597	0	15000	7187	16932	0	0	0
% Ash	4.66%	0.00%	7.05%	1.10%	0.00%	0.00%	0.00%	0.00%
Tons Ash	8,658.66	0.00	14.29	10.79	0.00	0.00	0.00	0.00

BIG STONE PLANT
FUEL BURN RECORD - page 1
May-04

DATE	Coal	P. Coke	TDF	Waste Seeds	Toner	Gran. Insul.	Canvas Belting	Plastic Chips
	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)
1-May-04	6,511.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2-May-04	6,541.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3-May-04	6,625.78	0.00	22.32	0.00	0.00	0.00	0.00	0.00
4-May-04	6,576.44	0.00	0.00	12.36	0.00	0.00	0.00	0.00
5-May-04	6,465.51	0.00	47.67	25.02	0.00	0.00	0.00	0.00
6-May-04	6,430.19	0.00	91.98	42.23	0.00	0.00	0.00	0.00
7-May-04	6,415.21	0.00	140.49	0.00	0.00	0.00	0.00	0.00
8-May-04	6,550.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9-May-04	6,401.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10-May-04	6,421.90	0.00	120.00	20.00	0.00	0.00	0.00	0.00
11-May-04	6,416.10	0.00	80.00	40.00	0.00	0.00	0.00	0.00
12-May-04	6,307.01	0.00	160.00	63.99	0.00	0.00	0.00	0.00
13-May-04	6,222.38	0.00	193.12	0.00	0.00	0.00	0.00	0.00
14-May-04	6,285.18	0.00	173.71	24.51	0.00	0.00	0.00	0.00
15-May-04	6,443.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16-May-04	6,479.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17-May-04	6,494.54	0.00	0.00	90.46	0.00	0.00	0.00	0.00
18-May-04	6,658.36	0.00	73.93	47.71	0.00	0.00	0.00	0.00
19-May-04	6,398.58	0.00	71.60	23.52	0.00	0.00	0.00	0.00
20-May-04	6,723.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21-May-04	6,680.82	0.00	49.89	44.49	0.00	0.00	0.00	0.00
22-May-04	6,840.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23-May-04	6,770.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24-May-04	6,602.04	0.00	122.04	63.12	0.00	0.00	0.00	0.00
25-May-04	6,529.43	0.00	71.65	98.32	0.00	0.00	0.00	0.00
26-May-04	6,681.67	0.00	49.55	71.88	0.00	0.00	0.00	0.00
27-May-04	6,939.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28-May-04	6,406.92	0.00	47.13	69.95	0.00	0.00	0.00	0.00
29-May-04	6,233.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30-May-04	6,376.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31-May-04	6,279.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Adjustment	2,000.00							
Total Burned	203,708.26	0.00	1,515.08	737.56	0.00	0.00	0.00	0.00
Total Delivered	211,380.43	0.00	1,515.08	737.56	0.00	0.00	0.00	0.00
HHV	8545	0	15000	7187	16932	0	0	0
% Ash	4.54%	0.00%	7.05%	1.10%	0.00%	0.00%	0.00%	0.00%
Tons Ash	9,256.53	0.00	106.81	8.11	0.00	0.00	0.00	0.00

BIG STONE PLANT
FUEL BURN RECORD - page 1
Jun-04

DATE	Coal	P. Coke	TDF	Waste Seeds	Toner	Gran. Insul.	Canvas Belting	Plastic Chips
	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)
1-Jun-04	6,214.61	0.00	52.18	70.31	0.00	0.00	0.00	0.00
2-Jun-04	6,324.20	0.00	47.41	94.19	0.00	0.00	0.00	0.00
3-Jun-04	6,255.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-Jun-04	4,258.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-Jun-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6-Jun-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7-Jun-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8-Jun-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9-Jun-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10-Jun-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11-Jun-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12-Jun-04	212.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13-Jun-04	5,015.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14-Jun-04	6,189.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15-Jun-04	6,332.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16-Jun-04	6,056.08	0.00	173.21	66.81	0.00	0.00	0.00	0.00
17-Jun-04	5,931.45	0.00	129.99	117.56	0.00	0.00	0.00	0.00
18-Jun-04	5,969.10	0.00	100.00	0.00	0.00	0.00	0.00	0.00
19-Jun-04	5,670.96	0.00	100.34	0.00	0.00	0.00	0.00	0.00
20-Jun-04	5,428.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21-Jun-04	5,776.89	0.00	93.49	22.22	0.00	0.00	0.00	0.00
22-Jun-04	5,786.29	0.00	73.01	23.10	0.00	0.00	0.00	0.00
23-Jun-04	6,311.23	0.00	155.07	0.00	0.00	0.00	0.00	0.00
24-Jun-04	6,567.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25-Jun-04	6,269.60	0.00	122.46	39.14	0.00	0.00	0.00	0.00
26-Jun-04	5,793.10	0.00	100.00	0.00	0.00	0.00	0.00	0.00
27-Jun-04	5,242.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00
28-Jun-04	5,978.85	0.00	96.97	44.18	0.00	0.00	0.00	0.00
29-Jun-04	6,439.56	0.00	95.02	49.52	0.00	0.00	0.00	0.00
30-Jun-04	6,402.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Adjustment	6,000.00							
Burned	136,424.32	0.00	1,439.15	527.03	0.00	0.00	0.00	0.00
Delivered	126,893.93	0.00	1,439.15	527.03	0.00	0.00	0.00	0.00
HHV	8460	0	15000	7187	0	0	0	0
% Ash	4.85%	0.00%	7.04%	1.10%	0.00%	0.00%	0.00%	0.00%
Tons Ash	6,611.92	0.00	101.32	5.80	0.00	0.00	0.00	0.00

B15 Fuel Analysis Record

BIG STONE PLANT COAL ANALYSIS PER TRAIN
Apr-04

DATE	TR #	MOIS. %	% ASH AR	HHV AR	S, % AR	% ASH DRY	HHV DRY	S, % DRY	NaO %	MAF HHV	COAL TONS	TONS OK
PREV. MON.	bam021	28.73	4.32	8753	0.26	6.06	12281	0.36	1.5	13073	14160.13	4198.66
PREV. MON.	ebm021	29.8	4.83	8526	0.4	6.88	12145	0.57	1.9	13042	12955.50	12955.50
1-Apr-04	0	0	0.00	0	0	0	0	0	0	0	0.00	
2-Apr-04	0	0	0.00	0	0	0	0	0	0	0	0.00	
3-Apr-04	bam22	29.18	4.29	8626	0.27	6.06	12180	0.38	1.5	12966	14160.98	14160.98
4-Apr-04	bam23	28.84	4.64	8625	0.3	6.52	12121	0.42	1.4	12966	13350.00	13350.00
5-Apr-04	0	0	0.00	0	0	0	0	0	0	0	0.00	
6-Apr-04	0	0	0.00	0	0	0	0	0	0	0	0.00	
7-Apr-04	bam24	28.87	5.08	8607	0.29	7.14	12100	0.41	1.3	13030	9835.43	9835.43
8-Apr-04	bam25	28.87	4.87	8669	0.32	6.84	12187	0.45	1.4	13082	13773.15	13773.15
9-Apr-04	0	0	0.00	0	0	0	0	0	0	0	0.00	
10-Apr-04	bam026	28.83	4.85	8651	0.3	6.82	12156	0.42	1.4	13046	14166.35	14166.35
11-Apr-04	bam27	28.89	4.71	8622	0.28	6.63	12125	0.4	1.5	12986	13800.53	13800.53
12-Apr-04	0	0	0.00	0	0	0	0	0	0	0	0.00	
13-Apr-04	0	0	0.00	0	0	0	0	0	0	0	0.00	
14-Apr-04	bam28	29.3	4.34	8628	0.27	6.14	12204	0.38	1.6	13002	14140.08	14140.08
15-Apr-04	bam29	28.83	4.36	8672	0.26	6.12	12185	0.37	1.5	12979	9536.70	9536.70
16-Apr-04	0	0	0.00	0	0	0	0	0	0	0	0.00	
17-Apr-04	0	0	0.00	0	0	0	0	0	0	0	0.00	
18-Apr-04	ebm22	29.72	4.99	8478	0.39	7.1	12063	0.56	1.7	12985	13080.60	13080.60
19-Apr-04	0	0	0.00	0	0	0	0	0	0	0	0.00	
20-Apr-04	bam30	29.69	4.20	8618	0.26	5.98	12257	0.37	1.5	13037	12762.73	12762.73
21-Apr-04	0	0	0.00	0	0	0	0	0	0	0	0.00	
22-Apr-04	0	0	0.00	0	0	0	0	0	0	0	0.00	
23-Apr-04	ebm23	30.3	4.77	8474	0.39	6.84	12158	0.56	1.9	13051	14181.68	14181.68
24-Apr-04	0	0	0.00	0	0	0	0	0	0	0	0.00	
25-Apr-04	bam31	29.12	4.66	8595	0.26	6.57	12126	0.37	1.5	12979	14163.73	14163.73
26-Apr-04	0	0	0.00	0	0	0	0	0	0	0	0.00	
27-Apr-04	0	0	0.00	0	0	0	0	0	0	0	0.00	
28-Apr-04	ebm24	29.83	4.77	8525	0.44	6.8	12149	0.62	2	13035	12989.30	11789.97
29-Apr-04	bam32	28.56	4.24	8684	0.27	5.94	12156	0.38	1.5	12924	14149.70	
30-Apr-04	0	0	0.00	0	0	0	0	0	0	0	0.00	
ADJ.												185896.06
											Tons. OK	185896.06
Weighted Average		29.29	4.66	8597	0.32	6.59	12157	0.45	1.58		Burn	185896.05

Monthly Mercury Analysis

Train #	Sample #	% Moist.	Mercury ug/g dry basis	Chloride ug/g
		30.14	0.116	<0.01

BIG STONE PLANT	COAL ANALYSIS PER TRAIN May-04

DATE	TR #	MOIS. %	% ASH AR	HHV AR	S, % AR	% ASH DRY	HHV DRY	S, % DRY	NaO %	MAF HHV	COAL TONS	TONS OK
PREV. MON	ebm24	29.83	4.77	8525	0.44	6.8	12149	0.62	1.98	13035	12989.300	1199.330
PREV. MON	bam32	28.56	4.24	8684	0.27	5.94	12156	0.38	1.51	12924	14149.700	14149.700
1-May-04	0	0	0	0	0	0	0	0	0	0	0.000	
2-May-04	ebm25	30.32	4.93	8396	0.4	7.07	12050	0.57	1.82	12967	14183.200	14183.200
3-May-04	bam33	29.16	4.28	8647	0.23	6.04	12207	0.33	1.48	12992	14158.475	14158.475
4-May-04	0	0	0	0	0	0	0	0	0	0	0.000	
5-May-04	bam034	29.17	4.32	8693	0.28	6.1	12273	0.4	1.57	13070	12965.900	12965.900
6-May-04	0	0	0	0	0	0	0	0	0	0	0.000	
7-May-04	0	0	0	0	0	0	0	0	0	0	0.000	
8-May-04	bam35	29.4	4.38	8587	0.29	6.2	12163	0.41	1.55	12967	12720.880	12720.880
9-May-04	0	0	0	0	0	0	0	0	0	0	0.000	
10-May-04	bam36	29.83	4.13	8578	0.27	5.89	12225	0.39	1.4	12990	14149.800	14149.800
11-May-04	0	0	0	0	0	0	0	0	0	0	0.000	
12-May-04	bam37	29.88	4.53	8511	0.31	6.46	12138	0.44	1.46	12976	14167.225	14167.225
13-May-04	0	0	0	0	0	0	0	0	0	0	0.000	
14-May-04	bam38	29.56	4.61	8594	0.3	6.55	12201	0.42	1.47	13056	14157.850	14157.850
15-May-04	0	0	0	0	0	0	0	0	0	0	0.000	
16-May-04	bam39	29.55	4.35	8643	0.29	6.18	12268	0.41	1.54	13076	14156.550	14156.550
17-May-04	0	0	0	0	0	0	0	0	0	0	0.000	
18-May-04	0	0	0	0	0	0	0	0	0	0	0.000	
19-May-04	bam40	29.59	4.63	8563	0.3	6.57	12161	0.43	1.56	13016	14149.900	14149.900
20-May-04	ebm26	30.26	4.94	8406	0.38	7.09	12053	0.55	1.72	12973	14187.275	14187.275
21-May-04	0	0	0	0	0	0	0	0	0	0	0.000	
22-May-04	0	0	0	0	0	0	0	0	0	0	0.000	
23-May-04	bam041	29.12	4.69	8581	0.33	6.61	12107	0.46	1.4	12964	14151.225	14151.225
24-May-04	ebm027	30.78	4.81	8386	0.41	6.95	12115	0.59	1.8	13020	13105.525	13105.525
25-May-04	0	0	0	0	0	0	0	0	0	0	0.000	
26-May-04	0	0	0	0	0	0	0	0	0	0	0.000	
27-May-04	ebm028	30.36	4.68	8431	0.41	6.72	12106	0.59	1.76	12978	14151.046	14151.046
28-May-04	0	0	0	0	0	0	0	0	0	0	0.000	
29-May-04	0	0	0	0	0	0	0	0	0	0	0.000	
30-May-04	ebm029	30.33	4.65	8445	0.41	6.68	12121	0.59	1.86	12989	14205.600	7954.379
31-May-04	ebm30	29.78	4.63	8500	0.39	6.6	12105	0.56	1.7	12960	14201.880	
ADJ.												203708.260
											Tons. OK	203708.260
Weighted Average		29.71	4.54	8545	0.32	6.47	12157	0.46	1.59		Burn	203708.260

Monthly Mercury Analysis

Train #	Sample #	% Moist.	Mercury ug/g dry basis	Chloride ug/g
	C817	29.19	0.086	<0.01

BIG STONE PLANT COAL ANALYSIS PER TRAIN Jun-04

DATE	TR #	MOIS. %	% ASH AR	HHV AR	S, % AR	% ASH DRY	HHV DRY	S, % DRY	NaO %	MAF HHV	COAL TONS	TONS OK
PREV. MO	ebm029	30.33	4.65	8445	0.41	6.68	12121	0.59	1.9	12989	14205.600	6251.221
PREV. MO	ebm30	29.78	4.63	8500	0.39	6.6	12105	0.56	1.7	12960	14201.880	
1-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
2-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
3-Jun-04	ebm031	30.21	4.76	8443	0.38	6.82	12098	0.55	1.7	12983	14154.15	14154.15
4-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
5-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
6-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
7-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
8-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
9-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
10-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
11-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
12-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
13-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
14-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
15-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
16-Jun-04	ebm32	29.94	4.84	8474	0.39	6.91	12096	0.56	1.7	12994	13927.43	13927.43
17-Jun-04	ebm33	29.35	4.87	8544	0.39	6.9	12094	0.55	1.9	12990	13905.63	13905.63
18-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
19-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
20-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
21-Jun-04	ebm34	30.22	4.58	8429	0.36	6.56	12079	0.52	1.8	12927	14156.00	14156.00
22-Jun-04	ebm35	30.23	4.84	8440	0.43	6.93	12097	0.62	1.8	12998	12427.50	12427.00
23-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
24-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
25-Jun-04	ebm36	30.08	4.59	8479	0.41	6.57	12127	0.58	1.8	12980	10909.80	10909.80
26-Jun-04	ebm37	30.21	4.63	8454	0.37	6.64	12113	0.53	1.8	12975	14144.95	14144.95
27-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
28-Jun-04	ebm38	29.61	4.86	8526	0.43	6.9	12112	0.61	1.7	13010	13080.90	13080.90
29-Jun-04	0	0	0	0	0	0	0	0	0	0	0.00	
30-Jun-04	ebm39	29.49	4.81	8523	0.38	6.82	12088	0.54	1.8	12973	9476.88	5174.24
ADJ.												118131.32
											Tons. OK	136424.42
Weighted Avg.		30.01	4.85	8460	0.38	6.93	12087	0.55	1.73		Burn	136424.32

Monthly Mercury Analysis

Train #	Sample #	% Moist.	Mercury ug/g dry basis	Chloride ug/g
	C1045	28.75	0.154	<0.01

B16 Ash Analysis Record

Sample Site: OTP Big Stone
Sample Description: OTP Fly Ash Sample
Sample Date: 23 Mar 2004

Analyte	Results	Units
SO3 in Ash	4.25	wt. %
Calcium Oxide in Ash	30.61	wt. %
Magnesium Oxide in Ash	6.88	wt. %
Sodium Oxide in Ash	2.81	wt. %
Potassium Oxide in Ash	0.51	wt. %
Aluminum Oxide in Ash	16.80	wt. %
Barium Oxide in Ash	0.87	wt. %
Iron Oxide in Ash	6.61	wt. %
Manganese Dioxide in Ash	0.06	wt. %
Silicon Dioxide in Ash	25.57	wt. %
Strontium Oxide in Ash	0.58	wt. %
Titanium Dioxide in Ash	1.38	wt. %
Phosphorus Pentoxide	1.22	wt. %
Arsenic	43.00	ug/g
Selenium	32.70	ug/g

Note: Unless otherwise idicated, results are on an As Received Basis.

B17 Ultimate Coal Analysis

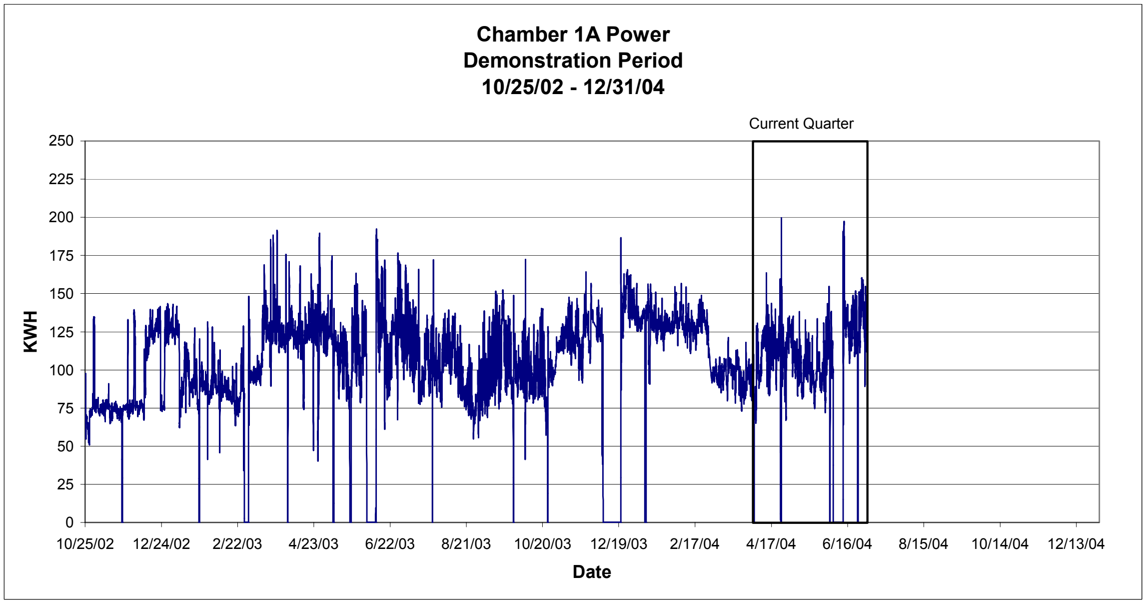
ULTIMATE ANALYSIS
AS RECEIVED

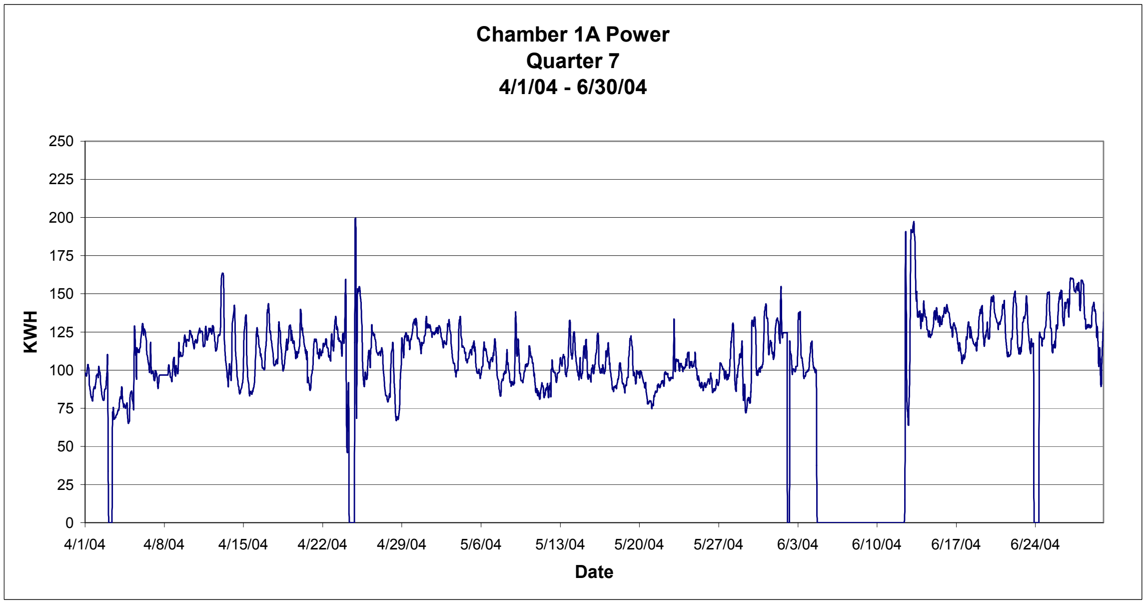
Sample Date	Moisture %	Ash %	Carbon %	Nitrogen %	Sulfur %	Hydrogen %	Oxygen %	HHV btu/lb	NaO %	Mercury ug/g Dry
04-Jan-04	29.76	5.09	48.59	0.70	0.44	3.44	11.98	8471	1.60	
11-Jan-04	29.33	4.62	49.57	0.69	0.33	3.38	12.08	8624	1.10	0.093
18-Jan-04	28.30	4.40	51.62	0.75	0.33	3.57	11.03	8602	1.70	
25-Jan-04	30.05	4.26	51.23	0.73	0.28	3.38	10.07	8548	1.70	
01-Feb-04	29.85	5.27	48.97	0.69	0.46	3.44	11.32	8503	1.80	
08-Feb-04	29.27	4.31	49.78	0.70	0.27	3.48	12.19	8604	1.40	0.035
15-Feb-04	30.58	4.38	49.39	0.68	0.26	3.34	11.37	8390	1.00	
22-Feb-04	29.67	4.99	49.05	0.70	0.44	3.59	11.56	8460	1.40	
29-Feb-04	28.68	4.83	50.30	0.73	0.43	3.36	11.67	8658	1.90	
07-Mar-04	29.65	4.70	50.04	0.69	0.34	3.43	11.15	8545	1.20	
14-Mar-04	28.54	4.87	50.47	0.72	0.40	3.49	11.51	8631	1.80	0.105
21-Mar-04	29.43	4.50	49.42	0.68	0.28	3.58	12.11	8543	1.70	
28-Mar-04	31.09	4.44	50.01	0.67	0.30	3.46	10.03	8428	1.50	
04-Apr-04	28.26	4.34	50.27	0.69	0.35	3.60	12.49	8712	1.80	
11-Apr-04	28.43	4.94	49.69	0.71	0.30	3.80	12.13	8622	1.50	0.089
18-Apr-04	28.75	4.22	50.96	0.67	0.26	3.36	11.78	8653	1.30	
25-Apr-04	29.68	4.72	49.54	0.68	0.38	3.36	11.64	8501	1.60	
02-May-04	28.11	4.51	51.45	0.66	0.41	3.47	11.39	8698	1.40	
09-May-04	29.19	4.46	50.73	0.62	0.30	3.50	11.20	8626	1.90	0.086
16-May-04	29.02	4.84	50.73	0.60	0.25	3.49	11.07	8581	1.30	
23-May-04	29.30	4.54	50.00	0.70	0.43	3.49	11.54	8528	1.60	
30-May-04	29.50	5.07	49.61	0.72	0.42	3.68	11.00	8449	1.40	
06-Jun-04	NA	NA	NA	NA	NA	NA	NA	NA	NA	
13-Jun-04	29.93	5.07	49.93	0.76	0.43	3.65	10.23	8352	1.40	
20-Jun-04	28.75	5.06	51.16	0.78	0.38	3.74	10.13	8516	1.70	0.154
27-Jun-04	29.40	4.71	49.98	0.68	0.40	3.68	11.15	8449	1.70	
04-Jul-04										
11-Jul-04										
18-Jul-04										
25-Jul-04										
01-Aug-04										
08-Aug-04										
15-Aug-04										
22-Aug-04										
29-Aug-04										
05-Sep-04										
12-Sep-04										
19-Sep-04										
26-Sep-04										
03-Oct-04										
10-Oct-04										
17-Oct-04										
24-Oct-04										
31-Oct-04										
07-Nov-04										
14-Nov-04										
21-Nov-04										
28-Nov-04										
05-Dec-04										
12-Dec-04										
19-Dec-04										
26-Dec-04										

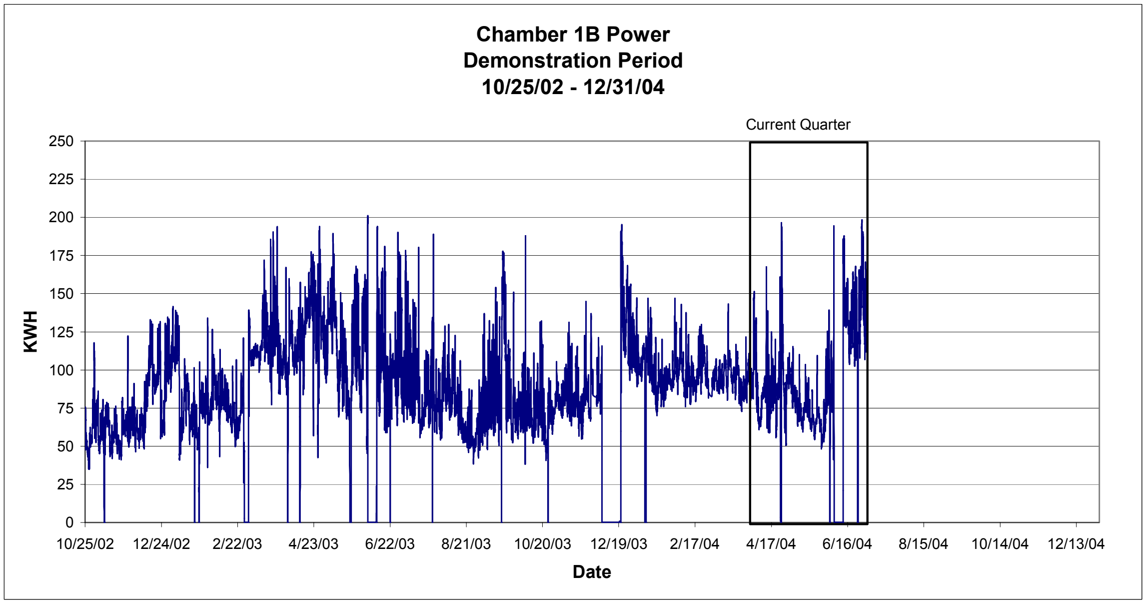
B18 Photographs

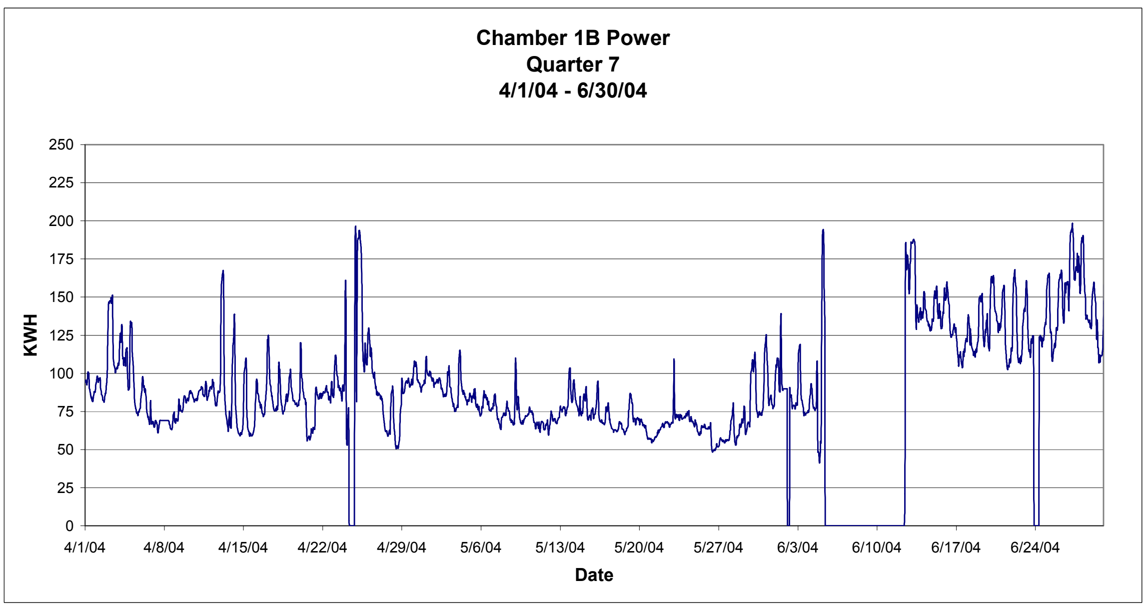
See Appendix B24

B19 ESP Power by Chamber






Chamber 1B Power
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
KWH
250
225
200
175
150
125
100
75
50
25
0
10/25/02
12/24/02
2/22/03
4/23/03
6/22/03
8/21/03
10/20/03
12/19/03
2/17/04
4/17/04
6/16/04
8/15/04
10/14/04
12/13/04
Date


Chamber 1B Power
Quarter 7
4/1/04 - 6/30/04
KWH
250
225
200
175
150
125
100
75
50
25
0
4/1/04
4/8/04
4/15/04
4/22/04
4/29/04
5/6/04
5/13/04
5/20/04
5/27/04
6/3/04
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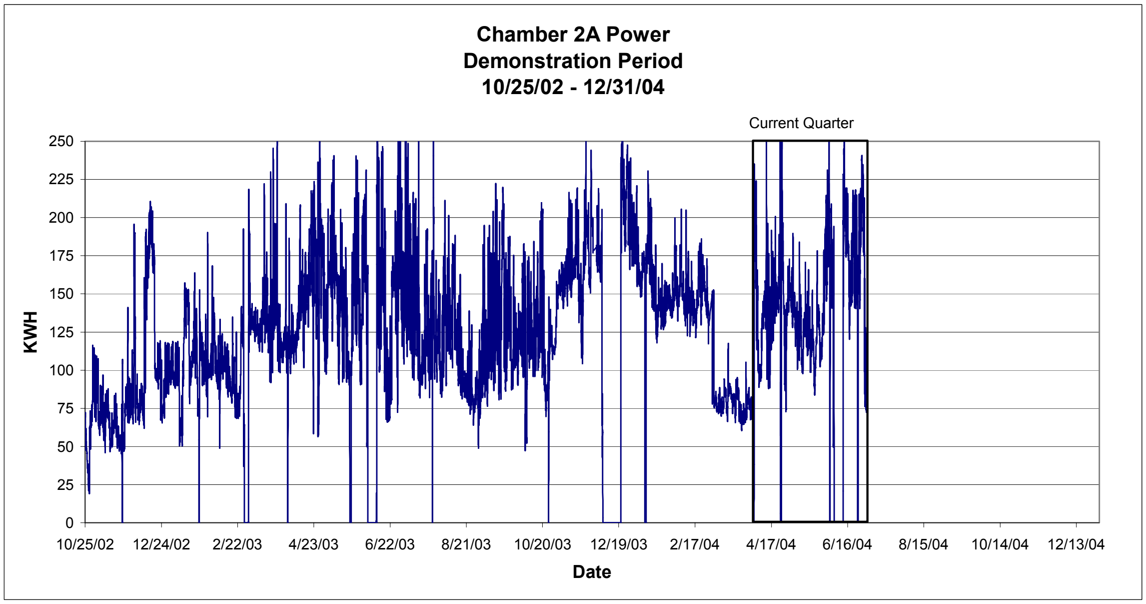
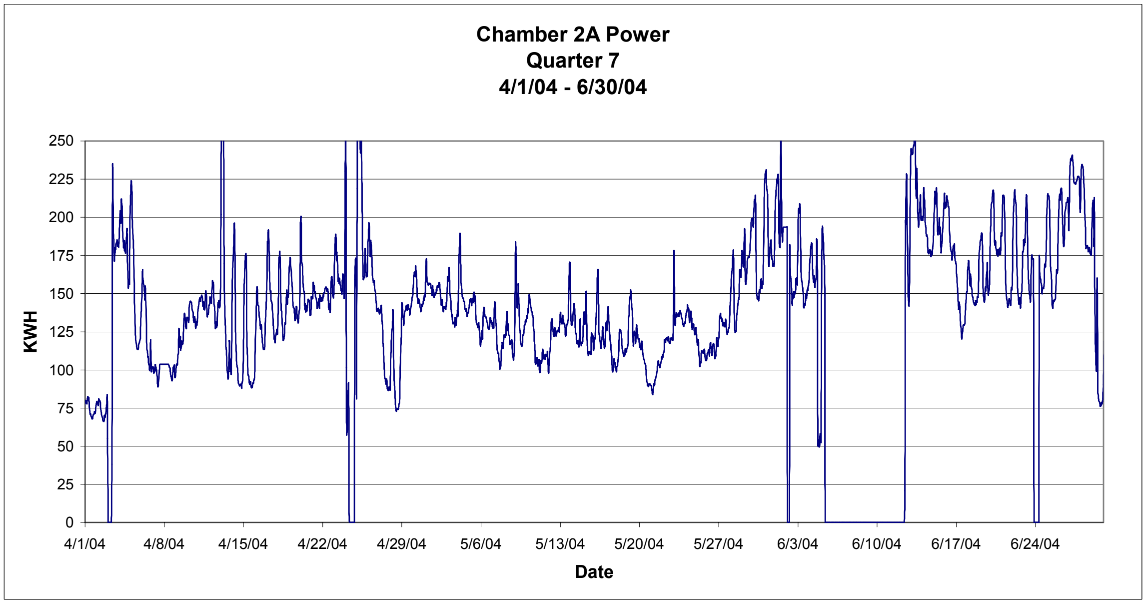
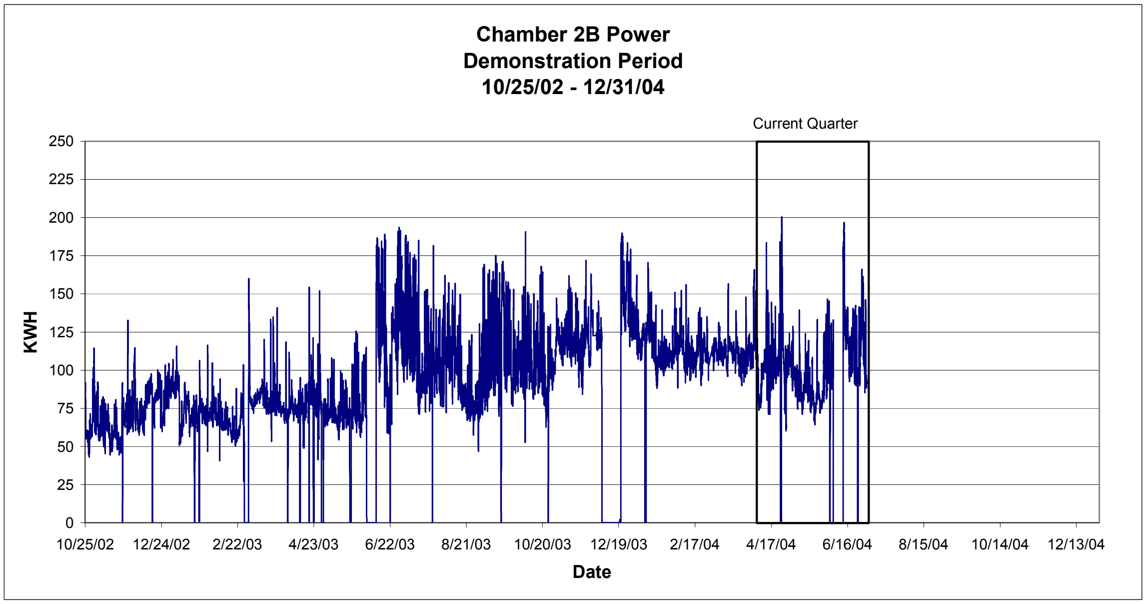
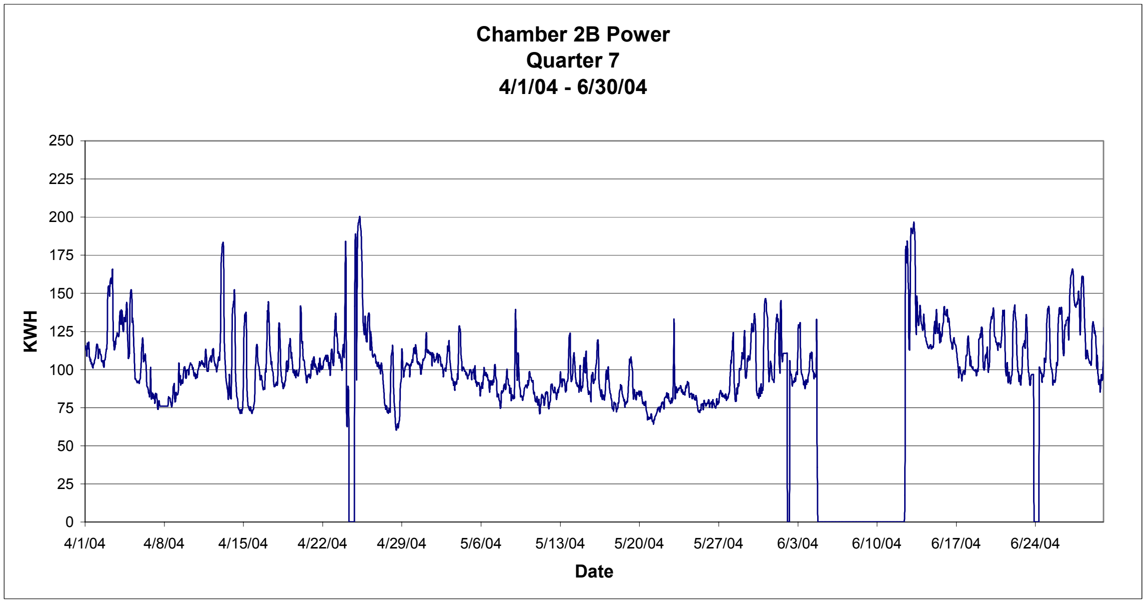
6/17/04
6/24/04
Date


Chamber 2A Power
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
KWH
250
225
200
175
150
125
100
75
50
25
0
10/25/02
12/24/02
2/22/03
4/23/03
6/22/03
8/21/03
10/20/03
12/19/03
2/17/04
4/17/04
6/16/04
8/15/04
10/14/04
12/13/04
Date


Chamber 2A Power
Quarter 7
4/1/04 - 6/30/04
KWH
250
225
200
175
150
125
100
75
50
25
0
4/1/04
4/8/04
4/15/04
4/22/04
4/29/04
5/6/04
5/13/04
5/20/04
5/27/04
6/3/04
6/10/04
6/17/04
6/24/04
Date



Chamber 2B Power
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
KWH
Date
250
225
200
175
150
125
100
75
50
25
0
10/25/02
12/24/02
2/22/03
4/23/03
6/22/03
8/21/03
10/20/03
12/19/03
2/17/04
4/17/04
6/16/04
8/15/04
10/14/04
12/13/04



Chamber 2B Power
Quarter 7
4/1/04 - 6/30/04
KWH
Date
250
225
200
175
150
125
100
75
50
25
0
4/1/04
4/8/04
4/15/04
4/22/04
4/29/04
5/6/04
5/13/04
5/20/04
5/27/04
6/3/04
6/10/04
6/17/04
6/24/04

B20 ESP Tabular Data

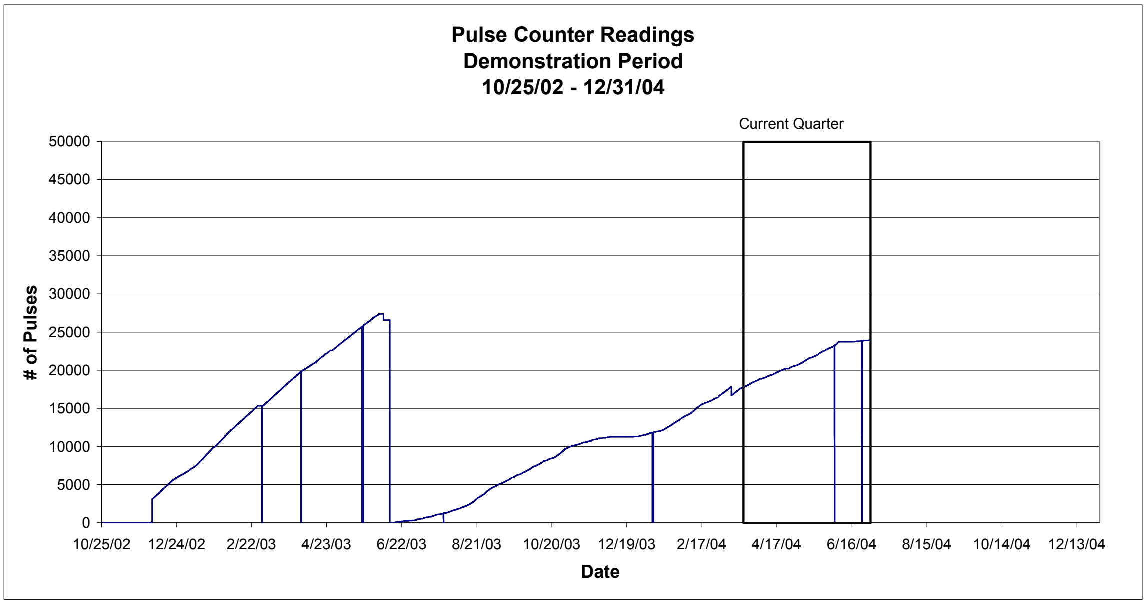
Transformer/Rectifier Performance Readings

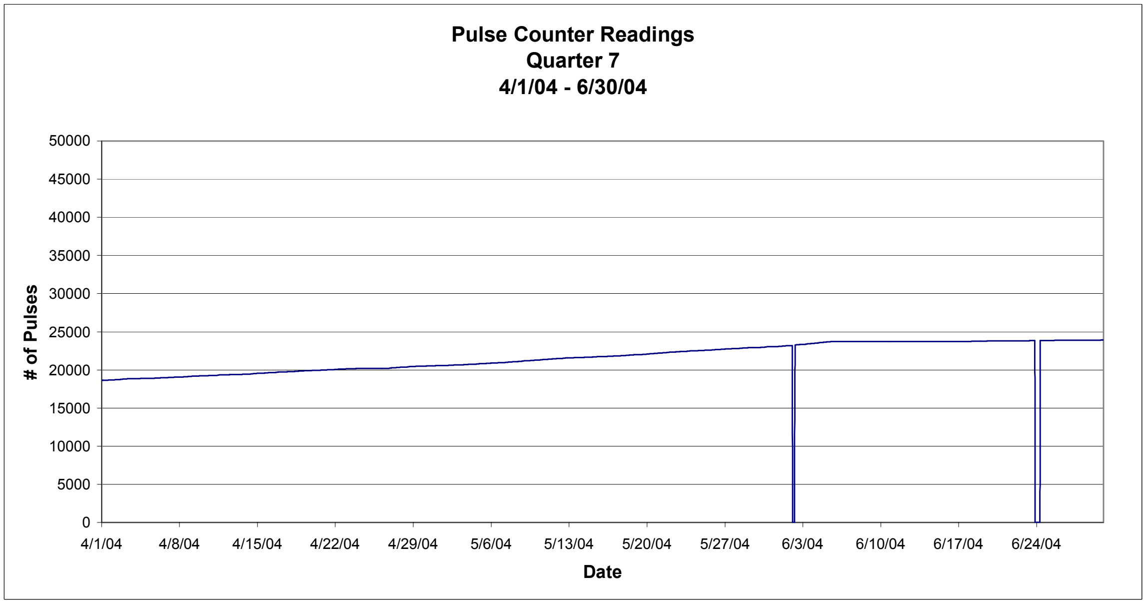
15-Apr-04	* Limiting factors highlighted											
Chamber	Field 1			Field 2			Field 3			Field 4		
	mA	kV	spm	mA	kV	spm	mA	kV	spm	mA	kV	spm
1A	94	64.9	4	610	49.2	19	975	52.1	8	981	56.3	7
1B	230	59.6	99	455	50.7	19	723	50.3	19	816	52.9	19
2A	421	63.6	55	704	55.5	19	682	55.4	19	905	51.6	18
2B	313	62.8	68	509	51.3	19	835	51.1	19	778	49.9	19

15-May-04	* Limiting factors highlighted											
Chamber	Field 1			Field 2			Field 3			Field 4		
	mA	kV	spm	mA	kV	spm	mA	kV	spm	mA	kV	spm
1A	425	64.4	30	481	47.3	19	870	49.7	19	881	54.4	19
1B	135	58.2	99	367	48.6	19	596	48.5	19	678	50.3	19
2A	445	64.4	38	646	53.3	19	592	52.7	19	814	50.1	19
2B	237	61.7	91	433	50.4	19	433	50.4	19	688	49.1	19

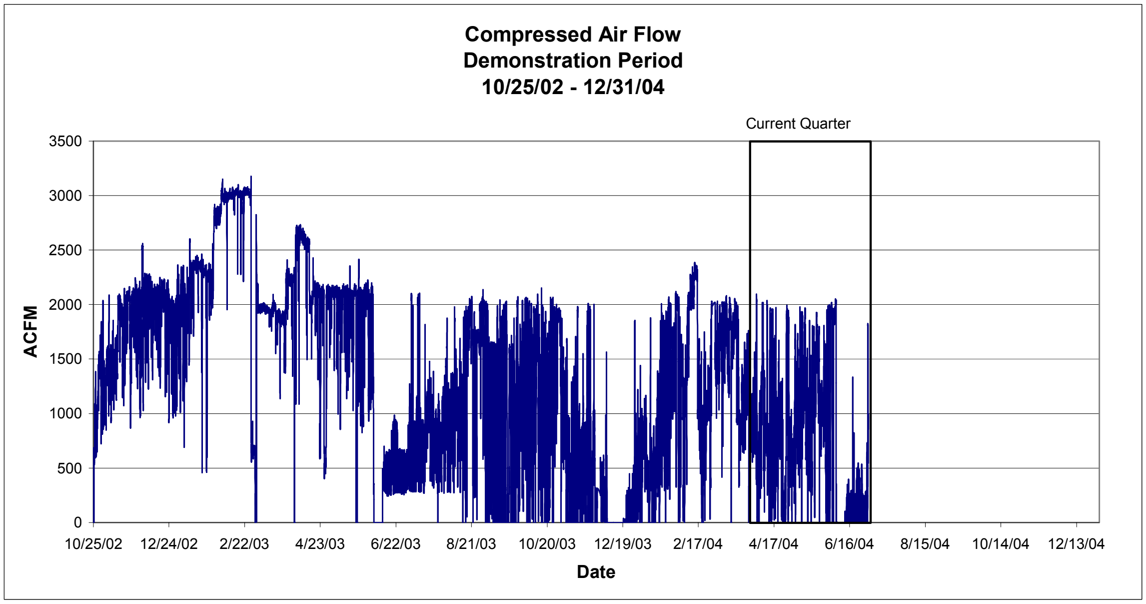
15-Jun-04	* Limiting factors highlighted											
Chamber	Field 1			Field 2			Field 3			Field 4		
	mA	kV	spm	mA	kV	spm	mA	kV	spm	mA	kV	spm
1A	64	64.8	12	533	47.9	19	887	49.6	18	972	55.1	11
1B	291	60.1	99	563	49.1	19	823	48.9	19	862	51.5	19
2A	334	64.7	17	706	53.8	19	671	53.8	19	913	50.3	18
2B	194	63.3	62	496	50.8	19	705	48.7	19	626	44.2	19

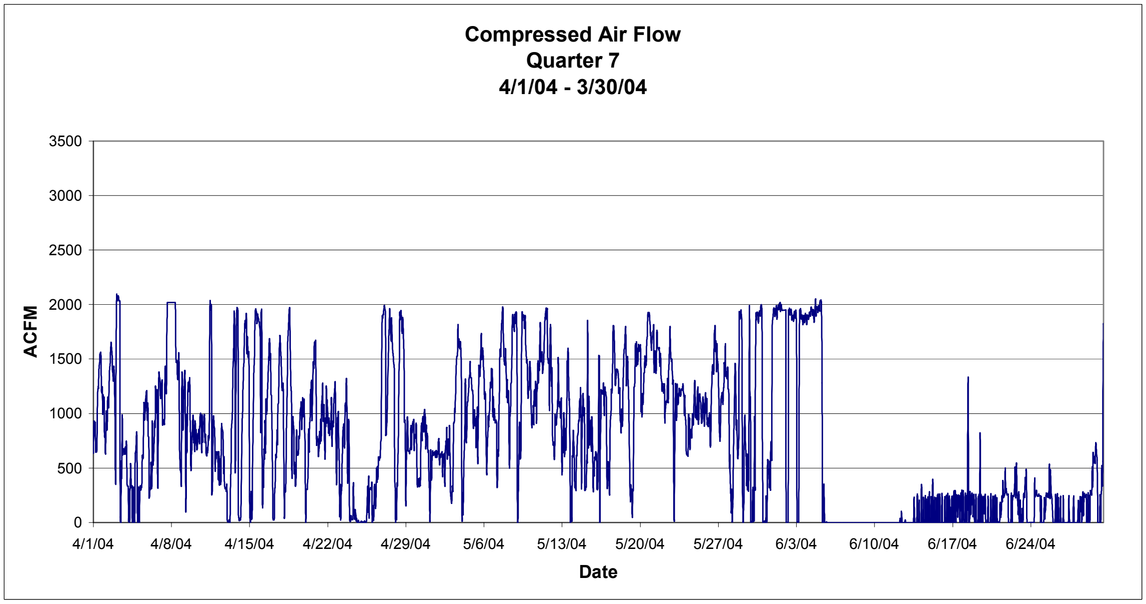
B21 Pulse Counter Readings





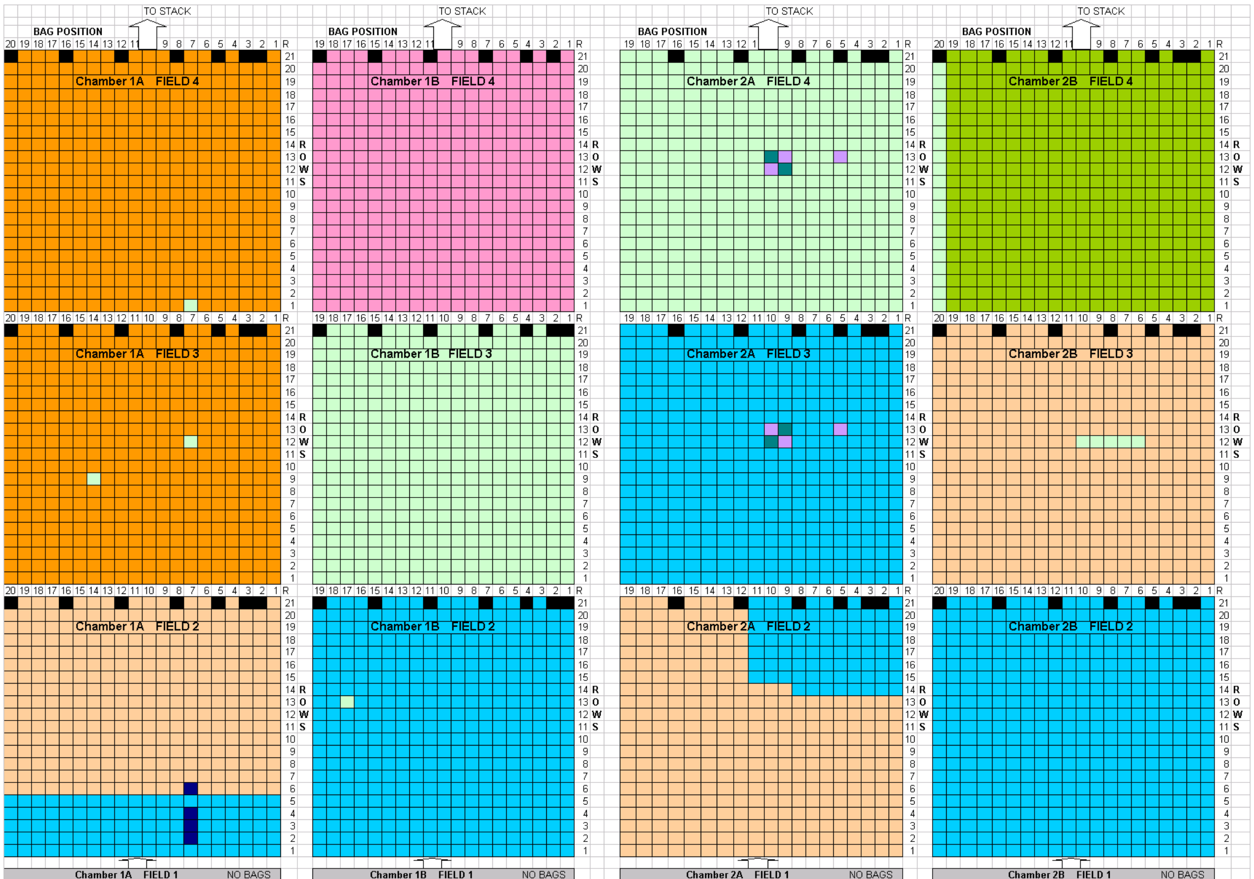
B22 Compressed Air Flow





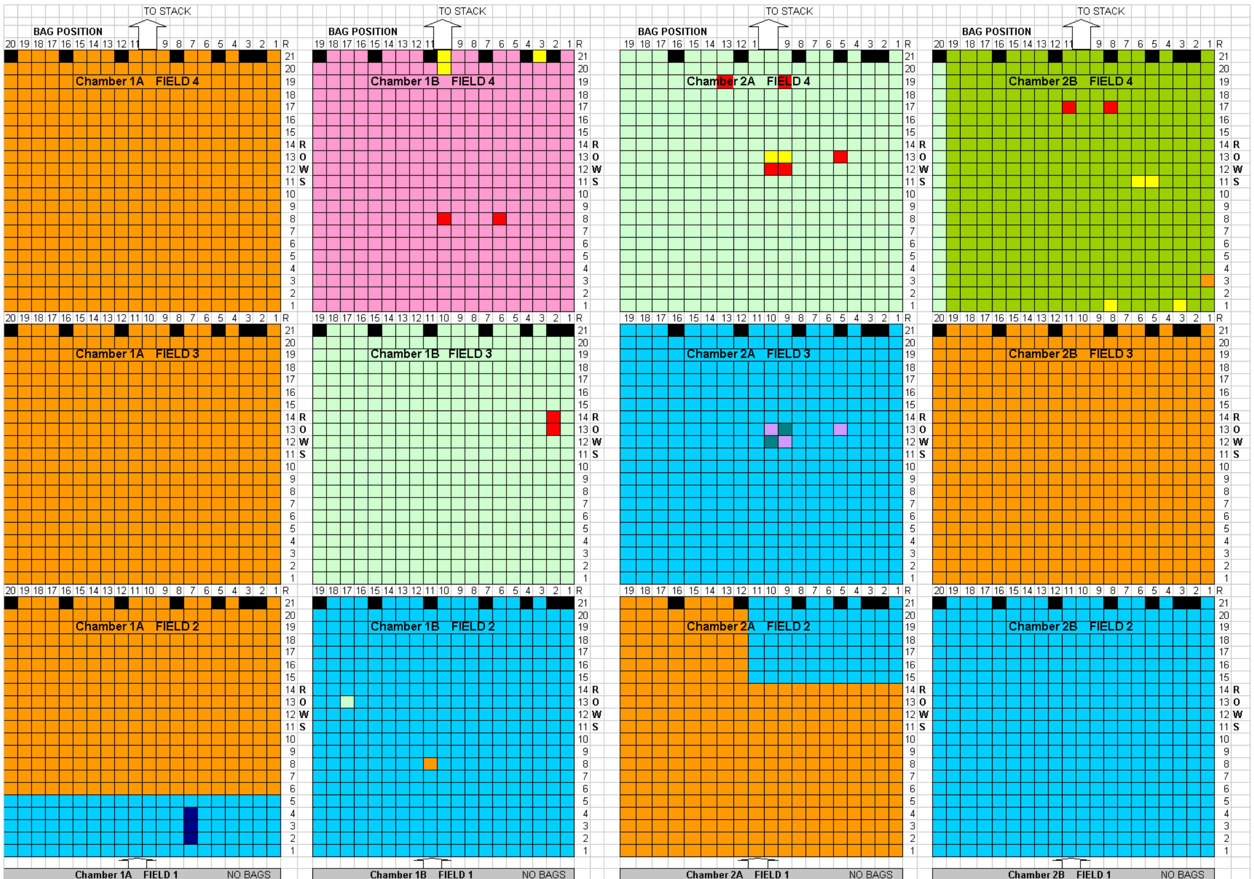
B23 Bag Layout Diagram

Bag layout prior to the June wash outage



No Filter Bag
Conductive Gore-Tex Membrane/Conductive Gore-Tex Felt (Installed 6/03)
Conductive Gore-Tex Membrane/Conductive PPS Felt (Installed 6/03)
Gore-Tex Membrane/PPS Felt (Installed 6/03)
Conductive Gore-Tex Membrane/Conductive Gore-Tex Felt (Installed 10/02, removed 6/03, washed, reinstalled 12/03)
BHA-Tex Membrane/Nomex Felt (Installed 12/03)
BHA-Tex Membrane/P84 Felt (Installed 12/03)
BHA Stainless Steel Cage (Installed 12/03) with Conductive Gore-Tex Membrane/Conductive Gore-Tex Felt (Removed 6/03, washed, reinstalled 12/03)
Conductive Gore-Tex Membrane/Conductive Gore-Tex Felt (Installed 12/03)
Gore - Superflex (Installed 12/03)
Gore-Tex Membrane/Fiberglass (Installed 12/03)

Bag layout after the June wash outage



- No Filter Bag
- BHA-Tex Membrane/P84 Felt (Installed 6/04)
- Gore-Tex Membrane/Gore-Tex Felt (Installed 6/04)
- Gore-Tex Membrane/Gore-Tex Felt (Installed 4/04)
- Conductive Gore-Tex Membrane/Conductive Gore-Tex Felt (Installed 6/03)
- Conductive Gore-Tex Membrane/Conductive Gore-Tex Felt (Installed 10/02, removed 6/03, washed, reinstalled 12/03)
- BHA-Tex Membrane/Nomex Felt (Installed 12/03)
- BHA-Tex Membrane/P84 Felt (Installed 12/03)
- Conductive Gore-Tex Membrane/Conductive Gore-Tex Felt (Installed 12/03)
- Gore - Superflex (Installed 12/03)
- Gore-Tex Membrane/Fiberglass (Installed 12/03)

Advanced Hybrid Outage Report
June 4, 2004 – June 12, 2004

Prepared By:

Tom Hrdlicka
Plant Engineer

June 14, 2004

Summary of Work

1) Bag inspection
2) Bag replacement
3) Installed bag row baffles
4) Modified blowpipes
5) Moved pitot tubes to new locations and checked for proper orientation
6) Repair girder box and bus duct purge air supply line
7) Complete inspection of:
    a. Clean gas plenums (leaks, cracks, corrosion, ash on tubesheet, etc.)
    b. Discharge electrodes and plates for clearance issues and ash build-up
    c. Rapper shafts, pinwheels, hammers and anvils
    d. Girder boxes for leaks and insulator crock condition

Results and Discussion

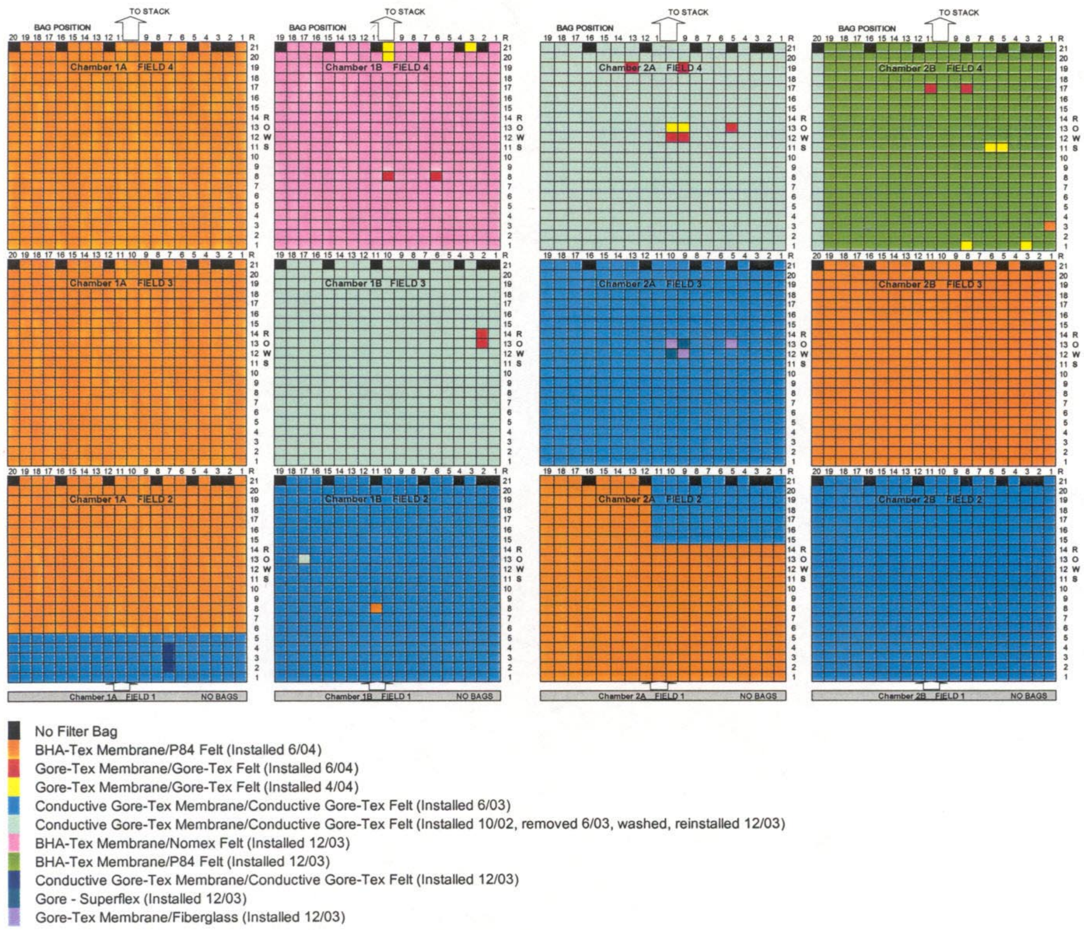
1) Bag Inspection

    a. Expectedly found holes in many nonconductive PPS/Gore-Tex bags in 1AF3 and 1AF4 as well as a few holes in the conductive PPS/Gore-Tex bags in 1AF2, 2AF2 and 2BF3. All the bags in these compartments have been in service for one year and were scheduled to be replaced during this outage.
    b. Found two all Gore-Tex bags with holes in the bottom of the bag, one was installed new in June 2003 (1BF2) and the other was an original bag that was washed and reinstalled in Dec 2003 (1BF3).
    c. One Nomex bag was found with a hole in 1BF4.
    d. The following bags were pulled to be sent in for analysis:
        i. 2 BHA-Tex/Nomex (one with a hole in it)
        ii. 1 Gore-Tex/Gore-Tex
        iii. 1 Gore-Tex/Fiberglass (installed with a 24 vertical wire cage)
        iv. 1 Gore-Tex/Fiberglass (installed with a standard 16 vertical wire cage)
        v. 1 Gore-Tex/Superflex
        vi. 2 BHA-Tex/P84
        vii. Two new BHA-Tex/P84 bags will also be sent in for analysis
        viii. ECC will perform the bag analysis and issue a report in mid July.
    e. Ten missing nozzles were also discovered and new nozzles were installed.

2) Bag Replacement

    a. SEI was contracted to replace 1928 filter bags. The replacement bags, provided by BHA Group, Inc., are 14 oz. P84 felt with a BHA-Tex membrane. SEI also replaced 13 additional bags using new Gore-Tex felt with Gore-Tex membrane bags (see updated bag layout below).
    b. The blowpipes came apart relatively easy and there were no extra charges incurred during this bag change due to difficult bag or cage removal.

Advanced Hybrid Bag Map
Big Stone Plant



3) Installed Bag Row Baffles (see Figure1-3 below)

   a. SEI was contracted to fabricate and install 57 sets of bag row baffles. The baffles were installed in all compartments of chamber 2B.
      i. Half of the baffles had to be modified because of incorrect fabrication.
      ii. Once the modifications were made, all three compartments were installed in only two days.
      iii. The decision was made to tack weld the nuts on to support bracket bolts and also to tack weld the ends of the baffles near the bottom to maintain a 2-inch gap.
      iv. There is some concern surrounding the clearance between the bag and the cut out portion of the end baffles.

Figure 1: Installed baffles viewed from below.

Figure 2: End baffle without tack weld

Figure 3: End baffle with tack weld

4) Modified Blowpipe

a. One compartment of blowpipes was modified in 1BF3 (see Figure 4)
b. Flat bar was used to seal off the holes for the top header (see Figure 5)

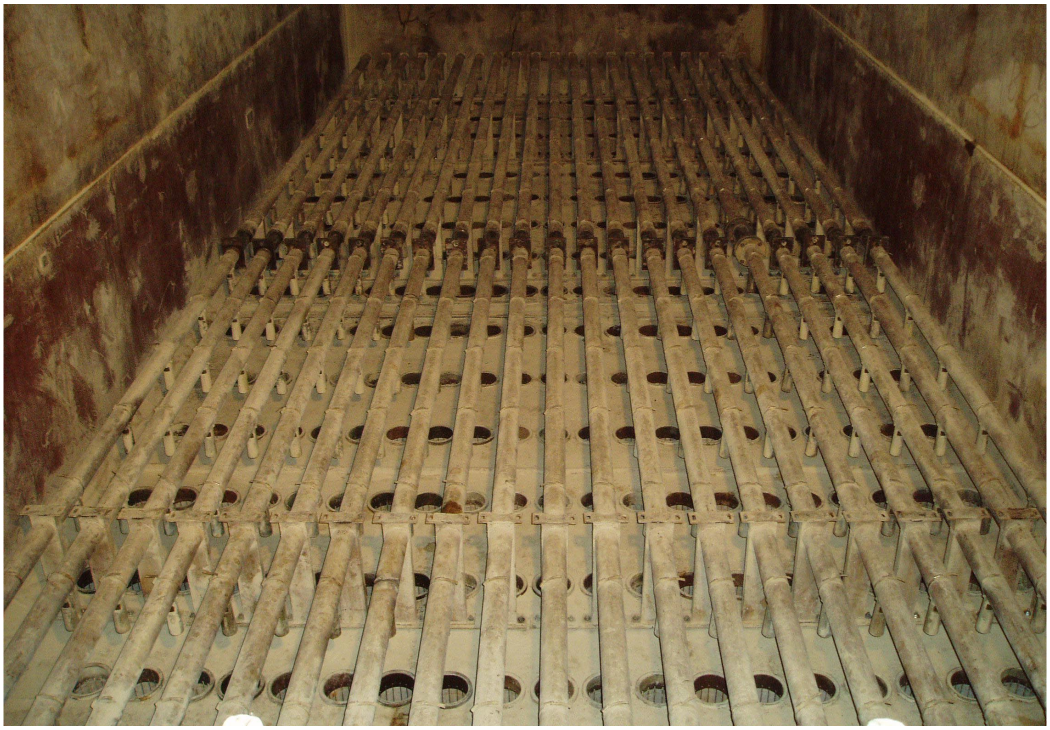


Figure 4: Modified blowpipes in 1BF3

Figure 5: Flat bar used to cover holes in plenum wall

5) Pitot Tubes

   a. Pitots were repositioned in 1BF3 to monitor the modified blowpipes and 2BF3 to help determine the effectiveness of the baffles.

6) Repair Purge Air Supply Lines

   a. SEI repaired four girder box and bus duct purge air supply lines. The PVC lines installed in Oct. 2002 were warped due to heat. Metal ducting was installed (see Figures 6-7).

Figure 6. New girder box purge line

Figure 7: Purge line interface to girder box

7) Complete Inspection

   a. Discharge electrodes and plates
      i. Discharge electrodes have a thin layer of ash that is uniformly distributed. The ash brushes off with a soft bristle brush.
      ii. The plates also had a thin layer of ash that is uniformly distributed. No buildup near the top of the plates was observed and no holes were plugged.
      iii. No obvious clearance issues were reported.
   b. Rappers
      i. The majority (95%) of the hammers are striking the anvils on center with the remainder within 1 cm.
      ii. No broken hammers or rapper components were reported.
   c. Girder Boxes

i. No ash buildup in the girder boxes.
ii. No cracked insulator crocs reported.

d. Clean Gas Plenums

i. Amount of corrosion on ceilings has increased from last inspection (see Figure 8). Noted water dripping in around one top hatch (see Figure 9).

Figure 8. Corrosion on plenum ceiling

Figure 9. Plenum top hatch corrosion

Recommendations

- 10 filter bags will be sent in to ECC for analysis including 2 new P84 bags. The new bags will provide some baseline strength data that we do not have to date. Results will be available mid July.

- Standing water that is getting under the roof lagging is causing the corrosion. This problem needs further investigation to develop a solution.

- Pitots have been installed to monitor the modified blowpipes and chamber of baffles. They will have to be rotated on a regular basis to obtain data from different bags.

- The bags near the end baffles will have to be monitored closely. There is potential for abrasive wear and tearing for the bags in these positions.

B25 W.L. Gore and Associates Bag Report

Creative Technologies
Worldwide

Full scale *Advanced Hybrid*™ Filter Big Stone Demonstration Operation Site Filter Bag Analysis

Date: June 11, 2004
Prepared By: Dwight Davis

Background:

Plant Location:	Otter Tail Power Company, Big Stone City, South Dakota
Filter Bag Type:	GORE-NO STAT® (GORE-TEX® membrane conductive/GORE-TEX® felt), GORE-TEX® membrane/PPS (polyphenylene sulfide) felt, GORE-TEX®membrane/conductive PPS felt, SUPERFLEX®, GORE-TEX®membrane/woven fiberglass filter bags, NOMEX® and P-84 backed filter bags
Bag Diameter:	6.0 inch
Length:	7 meter
Air/Cloth:	10 to 12 fpm
Dust Type:	Fly Ash from Coal-Fired Boiler
Coal Type:	Eagle Butte, Belle Ayr Mine; Western Sub-bituminous

GORE-NO STAT® , GORE-TEX® membrane/PPS felt, GORE-TEX® membrane/conductive PPS felt, SUPERFLEX®, GORE-TEX®membrane/woven fiberglass filter bags were installed and pre-coated prior to the June 11, 2003 start-up of the full scale *Advanced Hybrid*™ Filter at Otter Tail Power Company's Big Stone Plant located in Big Stone City, SD. Refer to the June 11, 2003 bag locator guide found in the appendix. On July 14, 2003 a portion of the filter bags were exposed to a temperature excursion that exceeded their maximum temperature rating. Subsequently Big Stone took a derate to inspect and pull filter bags for analysis in two chambers on September 17th, and a third chamber on September 27th. On October 24th additional bags were pulled from three chambers for analysis. Big Stone remained in operation until the plant shutdown for a boiler wash on December 5, 2003. Operation resumed on December 20, 2003, with new bags replacing the all PPS filter bags in four of the compartments along with four trial SUPERFLEX® and six trial GORE-TEX® membrane/woven fiberglass filter bags. The filter bags pulled September 17th & 27th and October 24th for analysis, indicated the all PPS filter bags had been weakened in four of the compartments. This led to the four compartments' filter bags replacement during the December 2003 boiler wash shutdown. Two of the compartments were outfitted with previously used (Oct '02 to June '03) and washed off-line GORE-NO STAT® bags, the third compartment was outfitted with NOMEX membrane bags and the other with P-84 membrane bags. Refer to the December 2003 bag locator chart in the appendix for the replacement and trial filter bag location. On February 28th, 2004 the plant scheduled one last inspection and bag sampling derate prior to their June 2004 boiler wash outage.

As part of the Power Plant Improvement Initiative Big Stone Demonstration site DOE funding program, filter bags were removed for lab analysis when compartments or the entire *Advanced Hybrid*™ Filter were taken off line. Ten filter bags were removed on September 17th, one on September 27th, five on October 24th, and five additional filter bags on February 28th, , 2004.

Filter Bag Evaluation:

A total of twenty-one filter bags were removed over the nine month time period by W.L. Gore and Otter Tail Power Company personnel for evaluation purposes by W.L. Gore and Associates. Various tests including air permeability, felt strength using both Mullen Burst and Instron tensile strength tests, along with visual observations including membrane microscopic examination were undertaken.

Air Permeability Analysis

The air permeability analysis of the filter bag media was performed in the lab using the Frazierometer.

Permeability is the volumetric flow rate of air, measured in cubic feet per minute (cfm) through a square foot of filter media at a pressure differential of 0.5 inches water gauge (w.g.). The unit of measure is cfm/ft2 @ 0.5"w.g. and is called the Frazier Number (Fn). Samples of the *Advanced Hybrid*® filter bag media were cut from the top, middle, and bottom bag locations. The sample size was five inches in the vertical bag length direction along the entire circumference of the bag. Typically three measurements per bag sample were taken. An average value is then calculated from the nine measurements per bag.

Each sample is tested for permeability in the condition it was received from the field and again in the identical location after lightly brushing the dust cake. See Table 1:

Otter Tail Power Company
Big Stone Power Plant Improvement Initiative Demonstration Site
Filter Bag analysis summary chart - All Frazier #'s are reported as cfm/ft2@0.5 in.w.g. driving force

Location	Service Time	Max. exposed temp (F)	Backing	As rec'd (F-n)	Mullen Burst (psi)	Mullen Burst % Strength Retention	Tensile strength - cross machine direction (psi)	%Tensile strength retention - cmd	Tensile strength - machine direction (psi)	% Tensile strength retention - md	Comments
1BF3 R1B1	6/10/03 to 9/17/03	365	all PPS	2.9	249	72	113	39	83	61	membrane OK, tan felt color
1BF3 R1B3	"	365	all PPS	3.6	226	66					membrane cracking along some of the vertical cage wires
1BF3R1B4	"	365	all PPS	4	223	65					membrane cracking at vertical/horizontal cage wire junctures
1BF3 R1B6	"	365	all PPS	3.8	182	53			51	37	membrane delaminated during HEC cleaning
1BF3R1B7	"	365	all PPS	2.7	236	69	114	39	61	45	membrane cracking, tan felt color
2BF2 R3B5	"	500	all GT	1.9	717	100					membrane OK
2BF2 R3B8	"	500	all GT	1.5	735	100					membrane OK
2BF3 R19B6	"	500	cond PPS	2.3	481	96	181	54	243	100	membrane OK, chocalat brown felt color
2BF3 R19B7	"	500	cond PPS	2.2	473	94	180	54	200	83	bag turned inside out during removal
2BF4 R20B7	"	500	all PPS	2.8	208	60	90	31	73	53	membrane scraped during removal, dark tan felt color
1AF4 R11B11	6/10/03 to 9/27/03	322	all PPS	3.9	234	68	123	43	90	66	membrane cracking along vertical and horizontal cage wires
1AF4 R1B20	6/10/03 to 10/24/03	322	all PPS	3.6	368	78	104	36	42	31	membrane cracking in vertical direction between vertical cage wires
1AF4 R1B12	"	322	all PPS	4	229	67	73	25	24	17	membrane cracking at vertical/horizontal cage wire junctures, tan felt color
1BF3 R21B5	"	365	all PPS	6.9	203	59	48	16	10	8	holes formed through felt backer, choc. brown felt
1BF3 R21B6	"	365	all PPS	5	210	61	33	11	2	2	membrane delamination, holes in felt
2AF4 R21B14	"	450	cond PPS	2	463	92	115	34	197	82	tan discoloration, hole in felt
1AF2 R15B11	6/10/03 to 2/28/04	322	cond PPS	2.6	449	89	224	67	205	85	membrane OK
1AF3 R11B15	"	322	all PPS	3	214	59	125	43	78	57	holes formed at vertical/horizontal cage wire junctures
2AF4 R13B10	12/3/03 to 2/28/04	350	SUPERFLEX	3.5	870	100	483	100	405	100	membrane OK
2AF4 R13B9	"	350	Fiberglass	3.1	920	100	729	100	461	100	membrane OK, small areas scraped during removal
2BF4 R11B6	"	365	P-84	5.1	337		185		97		membrane delamination throughout entire length of bag
	new	80	NOMEX	5.4	513		408		160		brand new
			new all PPS		366		289		137		
			cond PPS		503		337		241		
			all GT		650						

Table 1. Test Results Summary Chart

All the filter bags when removed contained a thin layer of dust similar to typical coal fired boiler fabric filter particulate collector applications. This residual filter cake and filter bag media air permeability measurement is shown in the " as received Frazier numbers" column. After light brushing, all the filter bag perms returned to near new levels. It should be noted that the higher Frazier number readings occurred when the membrane was scraped during removal, had cracked due to a weakened backer, or had become delaminated.

Felt Strength

Mullen burst tests were run on a portion of samples taken for the air permeability measurements.

The test consists of applying pressure in the reverse direction of airflow on a three inch diameter filter bag sample, continuously increasing the pressure until the sample is ruptured.

The September 2003 sampled filter bags' physical strength of the GORE-TEX® felt backed and conductive PPS felt backed filter bags maintained their strength while the all PPS felt backed filter bags began to show some minor weakening. Once we noticed the weakening of the all PPS felt backed filter bags, we began running a second type of physical strength test using an Instron test device. The Instron measures the tensile strength in both the machine and cross machine direction of the felt using two 2 inch by 5 inch samples. The sample cut with the long dimension in the vertical direction as the filter bag hangs represents the machine direction, the other sample cut with the long dimension cut in the horizontal (circumference) direction represents the cross machine direction. The Instron tests confirmed the all PPS felt backed filter bags had begun to weaken and the results indicated the higher the temperature exposure, the weaker the felt backer had become. A second set of filter bags was pulled in October 2003 and proved the all PPS felt filter bag continued to become weaker as shown in the appendix. By February 2004 the conductive PPS backed filter bags began to exhibit early signs of strength loss, even at the maximum exposed temperature of 322 (F).

Visual and Microscope Analysis

As noted earlier, all the filter bags contained a thin layer of dust cake on the membrane surface, typical of most coal -fired boiler applications. The primary dust cake was easily brushed off all the filter bags. The filter bags were examined for membrane damage from electrostatic discharge or sparking using a microscope - none was observed. However, membrane cracking began to occur with all PPS backed filter bags with the first set removed in September 2003. The conductive PPS backed and GORE-NO STAT® filter bags membrane integrity remained intact. The filter bags pulled February 2004, after two and a half months service, SUPERFLEX® and fiberglass backed filter bags show no membrane or backer wear. The P-84 backed filter bag had from top to bottom areas where the membrane had become delaminated in 1 to 3 inch diameter sections. The redesign of the filter bag incorporated in the June 2003 bag install utilizing a double layer of material in the bottom cuff apparently solved the wear previous seen with the October 2002 installed bags. .

Conclusions:

- GORE-NO STAT® filter bags continue to maintain excellent membrane integrity and physical strength.

- Laboratory analysis of the filter bags revealed no membrane damage caused by electrostatic discharge or sparking.

- After 10 weeks of service SUPERFLEX® and fiberglass backed filter bags exhibited no loss in physical strength and membrane integrity.

- The all PPS backed and conductive PPS backed GORE-TEX® membrane filter bags have shown they are sensitive to temperature upsets.

- Future physical strength analysis should include Tensile strength testing, preferably using the Instron instrument.

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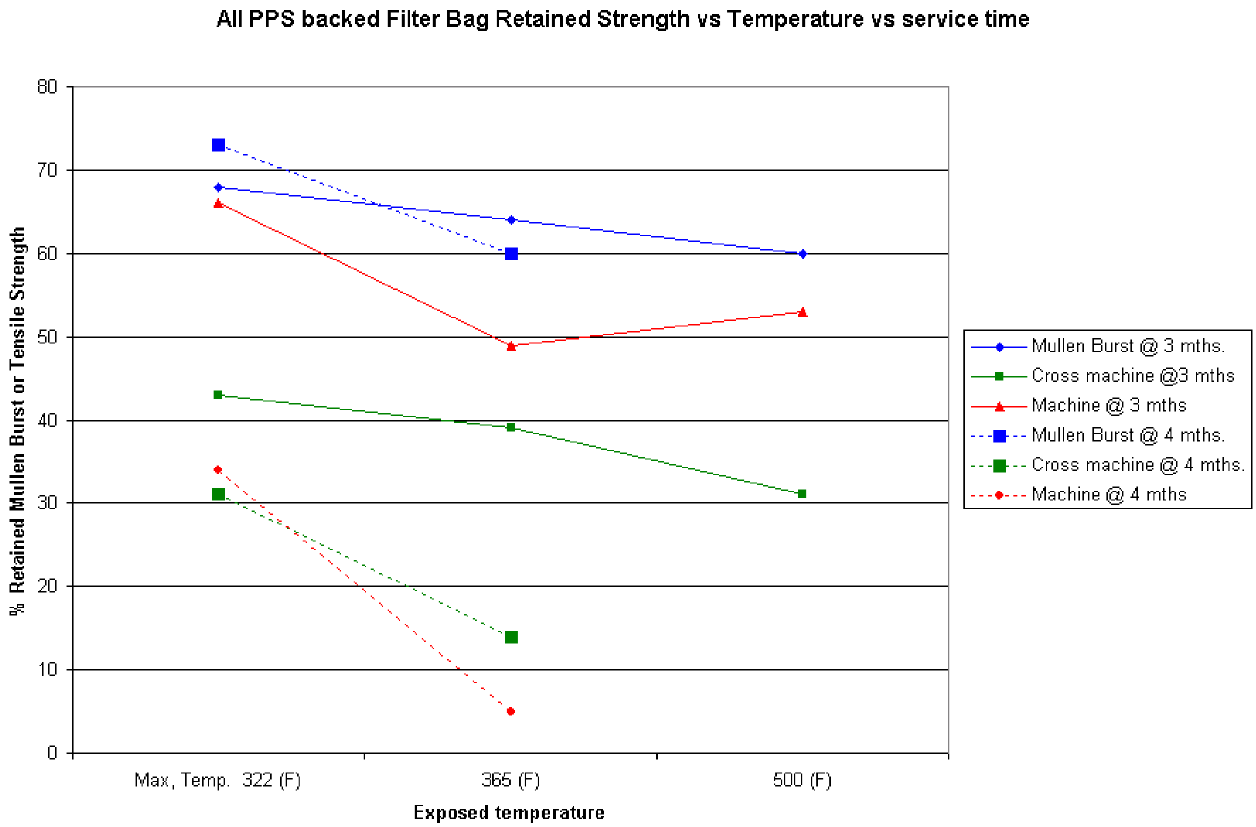
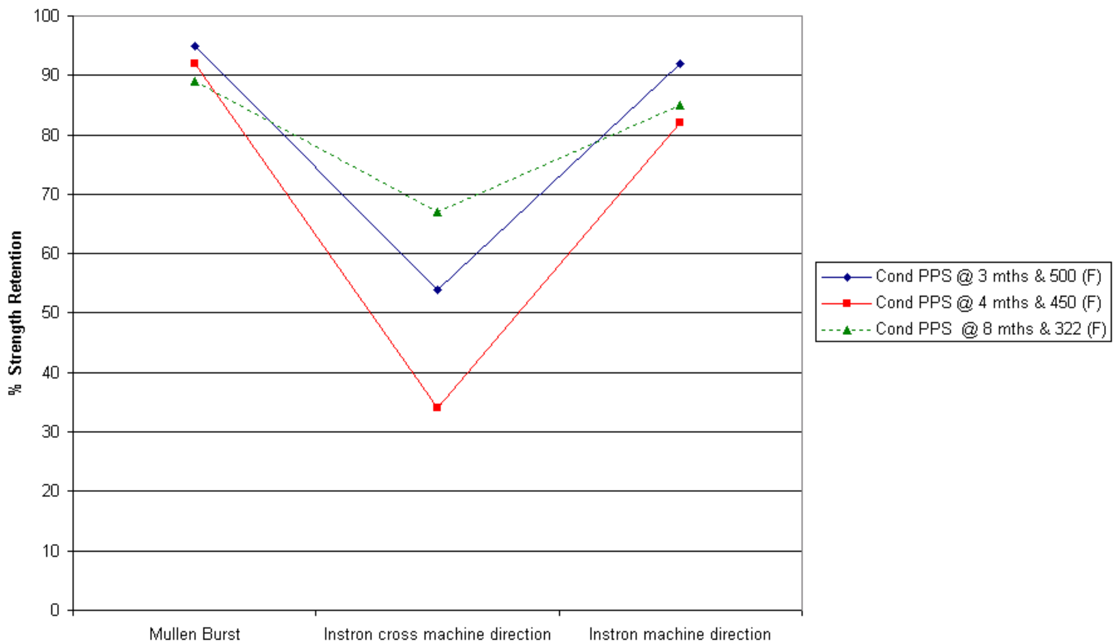
APPENDIX

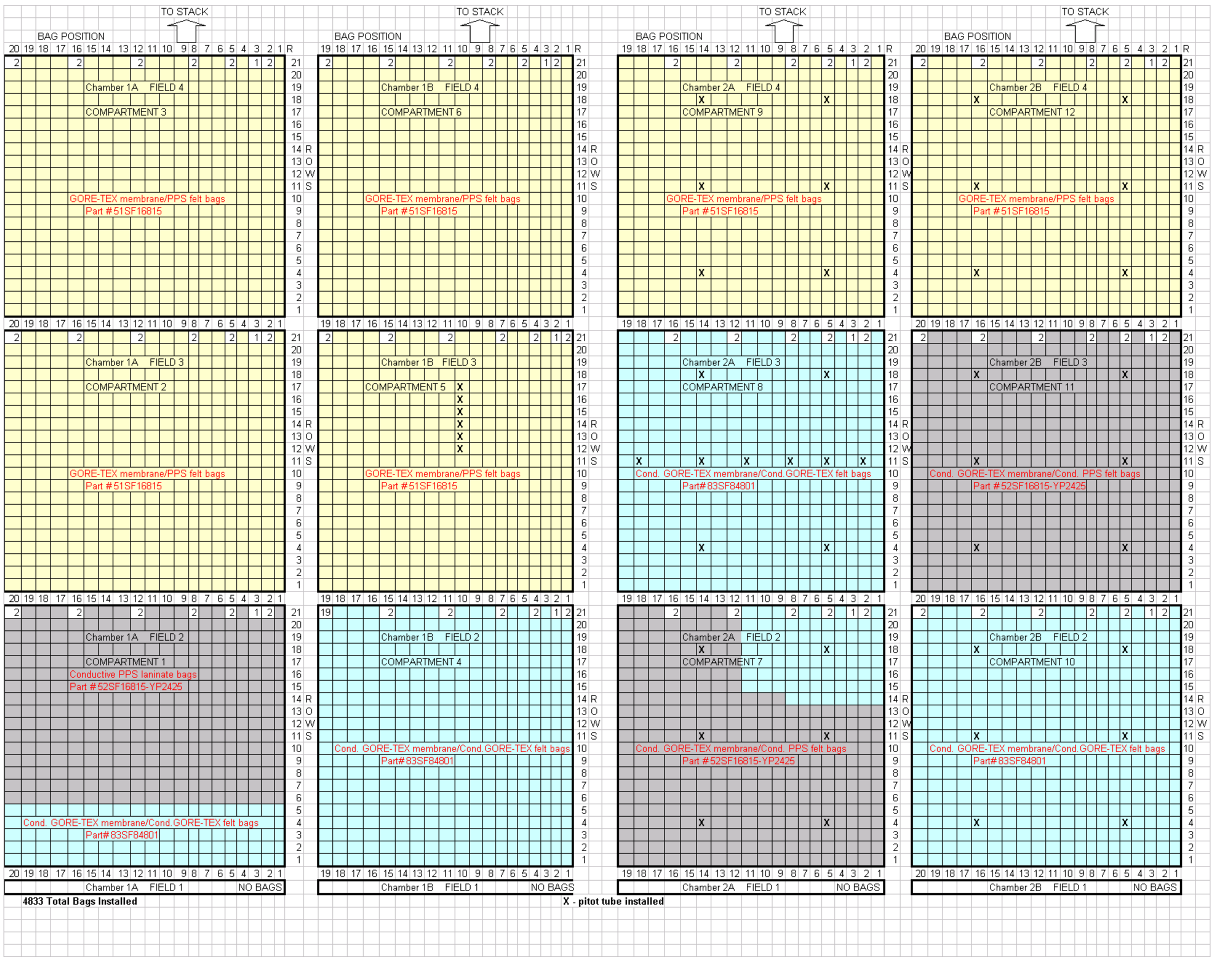


All PPS backed Filter Bag Retained Strength vs Temperature vs service time
80
70
60
50
40
30
20
10
0
% Retained Mullen Burst or Tensile Strength
Max, Temp. 322 (F)
365 (F)
500 (F)
Exposed temperature
Mullen Burst @ 3 mths.
Cross machine @3 mths
Machine @ 3 mths
Mullen Burst @ 4 mths.
Cross machine @ 4 mths.
Machine @ 4 mths

Physical strength retention of Conductive PPS backed filter bags vs temperature and service time



Bag Locator Chart for June 11



Bag locator guide for December 20, 2003